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EDITORS

EUGENE S. McCARTNEY

UNIVERSITY OF MICHIGAN

PETER OKKELBERG

UNIVERSITY OF MICHIGAN

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THE SAMOYED CULTURE

STANLEY D. DODGE

THE Samoyeds, who inhabit the tundras of northern Russia and northwestern Siberia, have a definite material cultural complex built around the reindeer. Their food, clothing and shelter, the three primary requisites for living, are obtained mainly from it. In addition, some of their spiritual beliefs have material accessories, accompanying certain rites, which involve the rangifer, and certain of the attributes of the deity of the Samoyeds are at least indirectly connected with this animal. There are, to be sure, a number of culture traits, both spiritual and material, which are not associated with the principal animal of the economy of the Samoyeds; it is, nevertheless, to the reindeer that the Samoyed looks for the primary requisites of his life, and it is the reindeer that he sacrifices in honor of the god Num.

According to Jackson,[1] the Samoyeds are one of the five divisions of the Ural-Altaic peoples, being related, thus, to the Finns, Turks, Mongols, and Tungus. The original home of this mongoloid family was in north-central Asia, and that of the Samoyed branch was in the basin of the Yenisei River, between the lofty Sayan and Altai Mountains. There is preserved in the museum at Minusinsk, in this region, a complete range of artifacts gathered from the Sayan-Altai basin of the Yenisei, which represent the transition from the use of bronze to the use of iron.[2] This collection is the anthropological triumph of the political exiles Martianoff and Alexander Kropotkin. The artifacts preserved there are similar to those of contemporary Samoyeds.

[1] F. G. Jackson, "Notes on Samoyeds of the Great Tundra," *Journal of the Anthropological Institute*, XXIV (1895): 388.

[2] Geo. F. Wright, *Asiatic Russia*, p. 253.

The relationship of the Samoyeds to the bronze and early iron age dwellers in the Minusinsk Basin rests, however, upon the stronger evidence of present day similarities between them and dwellers in isolated valleys of that region.[3] The theory is that, as the major portion of the Samoyeds moved out to the tundra, perhaps during a dry period corresponding to the epoch of the *Völkerwanderung*, the weaker members of the family remained behind, forming islands of ethnic retreat in the less hospitable valleys of the Sayan and Altai Mountains.

The name Samoyed has been given various meanings. By some it has been derived from *Sam yedin*, meaning 'himself alone,' and refers to what seemed to the Russians the strangeness of their solitary life. By others, the name has been taken as meaning 'self-eaters,' and as implying cannibalism, a trait likely to be imputed to one people by another, when the facts are unknown or insufficiently considered. The true meaning of Samoyed is probably much simpler. The Laplanders call themselves *Sambe*,[4] and there is a similar word in Finnish. In both cases these words mean nothing more than 'the people,' a meaning attaching to many racial and tribal names. In all probability, Samoyed, a similar word in a related language, has much the same significance.

The tundras inhabited by the Samoyeds extend from near the mouth of the Yenisei, in the vicinity of the Gulf of Ob and Taz on the east to the neighborhood of the Pechora River on the west. In speaking of them, the plural is ordinarily used, rather than the singular, which we use generically. These tundras stretch across Eurasia between the *Taiga* or Siberian forest and the Arctic Ocean. They are patches of frozen and partially frozen moor, with moss, lichen, grass, some rushes and tamarack (*Larix sp.*) as the vegetal association growing on them; they are separated by stretches of rocky waste, which are practically without vegetation. It is the patchy character of the occurrence of the moors that makes it possible to use the plural in speaking of them. Each tundra is occupied, for the most part, by a single

[3] *Ibid.*, p. 260.
[4] A. P. Engelhardt, *A Russian Province of the North*, p. 273.

tribe. Over it the Samoyeds of the tribe roam as they will with their reindeer during the warm season, allowing their animals to feed on the herbs of the partially frozen moor. When Edward Rae visited the Samoyeds of the region just east of the Pechora, as he tells in his book, *The White Sea Peninsula*,[5] he found them displeased with the coming of strangers. They asked, "Why do the strangers come to our *tundra*?", indicating awareness of definite ownership or exclusive control of one of the patches of moor that make up the cold desert which we collectively call tundra. The Russians have made use of this tundra-tribal organization in their administration of their arctic provinces. They allow each tribe to be governed, according to its local custom, by its own *starshinas*, that is, mayors and elders, one of whom is elected annually for each tundra.[6]

The Samoyed is dependent almost exclusively upon the reindeer for shelter, clothing and food. Wandering hither and thither, each tribe on its own tundra, they are nomadic herders. Near the shores of the Arctic Ocean, they add to their domestic animals the dog, for near the sea it is easy to obtain fish, and it is almost impossible to feed dogs in the arctic waste without fish.[7] Elsewhere but few dogs are kept, and these largely by the women, who use their fur as an accessory in the making of clothing.[8] Outside the area bordering the ocean, dogs are not used for transport. The Samoyeds, then, are nomadic, and, using the reindeer, adjust their way of living to the natural conditions which make wandering in search of pasture an essential part of existence.

In the movement of the Samoyed the reindeer is employed as a draught animal. The house, a little supply of food and fuel, the extra clothing, and the smaller children, if there be any, are loaded on the several deer which are used for transport, and the little, well-organized caravan, consisting of the family group, journeys to its new temporary home. The location of the home is determined by the nature of the vegetation which lies under

[5] P. 144.
[6] A. P. Engelhardt, *op. cit.*, p. 295.
[7] A. Erman, *Travels in Siberia*, p. 34.
[8] *Ibid.*, p. 76.

the snow. In this connection, Erman says:[9] "After a good journey with the reindeer we halted about 5 h. 30 m. on a level spot. Our drivers began busily to grope with their hands in the snow, and on pulling out tolerably large patches of lichen, the place was pronounced suitable for a night's lodging, and the reindeer were immediately unharnessed and turned loose." Can we doubt that the procedure would be the same if the stay were to be longer, and the Samoyed family were not encumbered with foreign travelers bent upon making a quick journey to some predetermined goal?

Once the location is selected by the man, the woman, as is the case among most nomadic peoples, erects the *choom*, or shelter. The *choom* is not unlike an Amerind tipi; it is made by laying skins over a cone of poles, the base being some fifteen feet in diameter, and the weight of the skins serving to keep the whole solid. "In covering the tent, the same principle . . . is . . . followed which is observable in the Ostyak[10] clothing, for immediately on the poles . . . is a layer of skins, with the hair turned inwards . . .; while a second layer . . . covers that, with the hairy side turned toward the air. For this purpose, long, ready lined strips of reindeer skin are permanently sewed together, and . . . are . . . very cleverly wrapped over the tent-frame."[11] Around the outside of the tent the snow is piled up with a wooden shovel till it is about a foot high. This serves to keep the air out. Inside a rush matting is placed by the woman for her master's bed. Reindeer skins and fur garments serve as resting places for the other members of the family and for guests. These are all spread on the snow, the thick blanket of which serves effectively to prevent drafts. In the meantime one of the men has cut down a larch sapling and has split it into small pieces for fuel. This is practically all the work that the men do in relation to the Samoyed domestic economy.[12]

Food, like the keeping of dogs, depends in part upon proximity to the sea. Near the Arctic Ocean, fish forms a part of the

[9] *Ibid.*, p. 68.
[10] A people living east of the Samoyeds and related to them.
[11] A. Erman, *loc. cit.* [12] *Ibid.*

regular diet, but for the greater number of the nomadic Samoyeds, that is, for those living in the interior and on the borders of the Siberian forest, reindeer meat is the staple article of food. The preparation of this food falls almost entirely on the women. According to Erman,[13] they always eat the flesh of the reindeer raw, whether it be quite fresh or old and frozen. According to Rae, however, the flesh is cooked,[14] which would seem to be the more usual practice. Erman, in all probability, witnessed the eating of frozen raw flesh, and concluded erroneously that it was customary.

From season to season some of the Samoyeds change the location of their grazing grounds. They are nearer the *taiga* in the winter, and on the shore of the Arctic Ocean in the summer, where they engage in fishing. The sparsity of population in the Samoyed tundra region allows this migration to take place with little jostling among the tribes. This seasonal movement, corresponding to the freezing and thawing of the arctic littoral, affects only a few of the Samoyed tribes; the others are more or less definitely located on specific tundras.

The Samoyed clothes himself in the skin of the reindeer and in furs that he gathers in the edges of the forest and elsewhere. The main garment of the men is the *malitsa*, or long tunic, made of reindeer skin, with a collar of fur. The hairy side of the skin is turned inward. In addition they wear fur boots, jackets and gloves, sometimes of deerskin. The tunic is ordinarily bordered with variegated stripes of fur, called the *panda*. Since the interior of the Samoyed *choom* is very warm, when the door is closed and a fire is burning within, a provision is made in the fur clothing for cooling the body. A long opening is left in the front of the garment, so that, when they are sitting within the tent with their backs to the wall, their breasts, which are exposed to the fire, may be left bare.[15]

It is through the *panda*, or border of the tunic, that the link exists between the material and the spiritual, for the rainbow

[13] *Ibid.*, p. 70.
[14] E. Rae, *The White Sea Peninsula*, p. 144.
[15] A. Erman, *op. cit.*, p. 70.

is supposed to be the *panda* of the *malitsa* of the god Num. Num, or Ylieumbarte, as he is sometimes called, is the ruler of heaven and earth, but he never descends to the unclean earth, lest he soil himself upon it, but communicates with man only through *tadebsty*, 'spirits,' who for this purpose choose *tadeby*, 'shamans' from among men.[16] Num knows everything that happens upon the earth; he rewards good with plenty of reindeer, and evil he punishes with poverty, for rewards of good and evil come in this life,[17] there being none beyond death. The god, then, is definitely a heavenly being, in spite of the fact that he has attributes in the form of clothing that are suggested by the variegated border of a mundane garment.

The Samoyeds have been converted to Christianity only partially. Their fundamental notions of Num, of good and evil and their rewards, their condemnation of theft, insult, murder, pride and excess, and their teaching of reverence for the gods, of honor to parents and elders, of succor to the needy, and so on, are, however, not far removed from the basis of Christianity, so that they have accepted a thin veneer of that religion. The Christian God is looked upon as a Russian Num; but St. Nicholas, the wonder-worker, has been taken over by them, and is held in particular veneration.[18]

In spite of the aloofness of Num, his manifestations to men are numerous. All the inexplicable phenomena of nature are his doing, the thunder, the lightning, rain, snow and tempests. He is embodied in the sun, moon and stars. The Samoyed religion would seem to be, therefore, but one step removed from animism, and to be, in that, akin to the Christianity of a prescientific era. In connection with the reindeer complex of the Samoyed, Num rewards good with many reindeer and punishes evil with a lack of them. The reward of reindeer as a manifestation of the justice of the deity indicates the place that the rangifer holds in the whole culture of the dwellers in the tundra.

The material accessories of religion, involving the reindeer,

[16] M. A. Czaplicka, *Aboriginal Siberia*, p. 289, note.
[17] E. Rae, *op. cit.*, p. 150.
[18] A. P. Engelhardt, *op. cit.*, p. 295.

are two in number, (1) the articles made of reindeer skin, and (2) the sacrifice of the animal itself.

(1) The propitiation of the *tadebsty*, or spirits, is done by shamans, the people themselves having recourse only to lesser household deities. Besides dress, which is made of reindeer skins, as it is for all Samoyeds, the shaman has a ceremonial drum of reindeer skin.[19] The drum is prepared by killing a male reindeer calf according to specific rules. This must be done by the shaman himself; women, being unclean, cannot assist. Afterwards the skin must be so prepared that no veins are left on it.[20]

(2) Although there is no actual belief in a future life, the Samoyeds reverence their dead and honor their memory long. The graves of the non-Christian are furnished with knife, axe, lance, and similar objects, for maintenance of the dead in the other world.[21] When a *tadeby* dies, two reindeer are fastened to the tomb to starve to death.[22] Apparently this is the most costly gift that can be devised that is suitable to the dignity of the intermediator between the Samoyeds themselves and the spirits of the outer world. Reindeer are also used in sacrifices to the spirits, which can be persuaded and propitiated thereby.[23]

In addition to the tadeby or spirits, which can be approached by shamans only, the Samoyeds have household and community idols, called *hegi*, which they may supplicate directly. These are natural or artificial semblances of the human body. Sometimes the Samoyeds sacrifice reindeer to the *hegi*, smearing the face with blood, and hanging the hide, hoofs and head near by.[24]

The Samoyeds have no regular temple or idol-sanctuary, but usually resort, for celebration of their rites, to well-known sites, on hills or in other localities, where reindeer or other wild animals are abundant. The island of Vaigatch is especially noted in this connection.[25]

The reindeer enters notably into the customs built up about the marriage relation. Wives are purchaseable, and the *kalym*,

[19] M. A. Czaplicka, *op. cit.*, p. 226.
[20] *Ibid.*
[21] E. Rae, *op. cit.*, p. 151.
[22] *Ibid.*
[23] A. P. Engelhardt, *op. cit.*, p. 277.
[24] E. Rae, *op. cit.*, p. 150.
[25] A. P. Engelhardt, *op. cit.*, p. 278.

or price, paid for one amounts sometimes to one hundred deer,[26] or a wife who is unsatisfactory may, at times, be sold for a few teams of reindeer. There is generally considerable bargaining for the bride, for the father is determined to get as much for his daughter as possible.[27] In case of divorce the *kalym* is returned, and should the woman die soon after marriage, the widower may claim its return, but he is sometimes kept from doing so out of a loving respect for the memory of the deceased.[28] There is a further present to the family of the purchased bride, this time to the mother, if it turns out after marriage that her daughter, when married, was a virgin. In return for the *kalym*, the bridegroom receives a dowry with the bride, equivalent to the price paid for her. The dowry always includes a *choom*, sledges, harness and meat, all of which, except sledges, are products of the reindeer.[29]

When the time appointed for the solemnization of the marriage arrives, the bridegroom repairs to the *choom* of the bride, where feasting takes place. The bridegroom pitches his *choom* at a distance from that of the bride's father, and, accompanied in the end by a number of strange women, goes to the bride's tent, where a certain number of presents are given. Then the bride is forcibly placed on a sledge by these women, and the rest of the sleds are loaded with the gifts which accompany her. The first three or four of these must be covered by the father with good cloth, and the rest with reindeer skins. Then the party returns to the groom's tent.[30] The bride does not go to her husband's home immediately, but waits till some time has elapsed. When she arrives, certain ceremonies are held which symbolize the capture of the bride.[31]

In the life of the Samoyed, the reindeer plays, therefore, a significant part. It bears his burdens, furnishes him with food, clothing, shelter, and ritual appliances, and it is an effective sac-

[26] M. A. Czaplicka, *op. cit.*, p. 125.
[27] P. S. Pallas, *Travels through Siberia and Tartary*, III: 12.
[28] M. A. Czaplicka, *loc. cit.*
[29] M. A. Czaplicka, *op. cit.*, p. 124.
[30] *Ibid.*
[31] *Ibid.*, p. 125.

rifice against the displeasure of the many spirits which haunt the world for good or ill. The rainbow, which is the appearance in the sky of the edge of the god's cloak, corresponds to the border of the reindeer garment worn by the Samoyed mortal. Therein is symbolized the spiritual and material culture complex that centers in the reindeer, the most important animal in a tundra environment.

University of Michigan

MATERIALS OF THE INDIAN LAPIDARY IN THE SAGINAW DISTRICT, MICHIGAN

FRED DUSTIN

IN THE *Report of the Smithsonian Institution for 1877*, Dr. Charles Rau has a paper on "The Stock-in-Trade of an Aboriginal Lapidary," in which he says: "There is little doubt that there were persons who devoted their time chiefly to the manufacture of stone arrow-heads and other stone artifacts, and that certain individuals who were either by natural inclination or practice particularly qualified for a distinct kind of manual labor, devoted themselves principally or entirely to that labor."

Early explorers, missionaries and traders have noted that certain Indians followed particular occupations, so that there were arrow-makers, wampum-makers, canoe-builders and other specialists.

The writer of this paper has personally collected over seven thousand Indian "relics" in Saginaw County, and has seen thousands of others in the possession of a score of other collectors. Even a casual observer cannot see many of these articles without being struck by the beauty of material and cleverness of workmanship. Red, yellow, brown and blue jasper, jetty-black lydian-stone or basanite, gray, red, brown and white agate, white quartzite, beautiful opaline chalcedony sometimes with drusy surfaces of crystal-clear quartz, bluish chalcedony from Flint Ridge, Ohio, translucent smoky chalcedony somewhat like English flint, but far more beautiful, clear vein quartz, and occasionally a black obsidian arrow-point from the far West: all these beautiful materials along with others are represented in our chipped artifacts.

We find pipes made from the red pipe-stone of Minnesota, animal figures fabricated from beautiful banded slate, and an occasional celt or axe pecked from a boulder filled with hornblende crystals or from granite of the finest texture.

The great mass of chipped implements and weapons are made of the common gray chert, or, as commonly called, flint. Pipes are worked out of limestone, sandstone, argillaceous rock, or rarely from some harder stone. Animal figures, "bird-stones," gorgets, and the like, are fashioned from black, red or brown slate. Axes, adzes, chisels, hammers and mauls are worked from common granite, gneiss, trap-rock, syenite and a half-dozen other common materials.

From whence came this supply? A glance at the map of our State, shows us five rivers converging in Saginaw County to form that estuary of Lake Huron known as Saginaw River, which, given a few hours of hard north wind, flows upstream some twenty miles or more. This is the largest river drainage basin in the State. The geological map of the State indicates that the southwest corner of the county is about the center of the Carboniferous formation, and that beneath this is a series of other formations lying in a shallow bowl or plate form and outcropping at various distances from the center according to the character of the formation. At Saginaw the Carboniferous formation is about two hundred feet below the surface, but thirty or forty miles south it outcrops nearly at the surface, as it also does in the southwest and north, while westward and to the northwest the rocks are buried deep under the drift and morainal deposits. Just across the east boundary of the county at Tuscola, there was formerly to be seen a ledge cutting the Cass River belonging to the Carboniferous, but the outcrop was small and is now said to be buried under alluvial or silty deposits. We see these rock formations taking a roughly circular form, and below the coal measures we will find sandstone, limestone of several descriptions, and shales or slaty rocks.

The Cass River, a few miles southwest of Cass City, runs over a succession of ledges dipping gently downstream. At this point we find a stratum of sandstone which forms the bed of the

river for eight or ten miles toward its source. Above the sandstone here, there outcrops a bluish clayey limestone of fine texture, which, when first removed, is quite soft, but on drying hardens somewhat. This was material used for making pipes, a number of which are in the writer's collection, some of nice workmanship and good design. In this limestone are numerous concretions of zincblende or sphalerite, and occasionally, a nodule of chert with sphalerite, making a quite pretty clouded agate plainly showing its metallic content. There are also druse cavities lined with blende crystals or dolomite spar or brownspar. Above this clayey limestone lie beds of shale and sand-rock along with a layer of hard limestone containing numerous chert concretions, thus furnishing a limited amount of material for the arrow-maker. This limestone formation again outcrops at Bay Port and was a source of unlimited supply, for the denuded rock was broken down and dissolved, leaving the hard nodules intact; also at Stony Island and Big Charity Island. In fact, the supply was sufficient for a far more numerous population than ever occupied our State in its primitive condition. These nodules are of much interest both to the mineralogist and archaeologist, and vary from the size of a marble to a diameter of some eight inches. At the Bay Port quarry they may be seen in place as well as at the locality on the Cass, but at the quarry, exposure is artificial, and as blasting goes on continuously, specimens are easily obtained and numerous vugs in the limestone may be explored for other minerals, while in some of the layers fossils are plentiful.

On July 13, 1924, the writer visited the quarry, and examined a few hundred feet of the north face of the workings, which at this point is ten or twelve feet high. The rock first exposed is a dirty-looking sandstone, about three feet thick, underneath which comes one and sometimes two layers of limestone each about two inches thick, and filled with simple coral fossils, mostly lying parallel to the bedding. The replacement material of which they are composed appears to be impure calcite, which stands out in marked contrast to the yellow-gray limestone matrix. Immediately below this comes the cherty limestone which outcrops on the bay shore, and contains thousands of nodules of chert, so

many, in fact, that in many portions of the quarry the stone is valueless for lime, while for road metal they are most useful owing to their hardness. Small masses of brown calcite crystals are numerous, their color probably coming from iron which often stains the limestone and sometimes forms small masses of lean iron ore.

At the bottom of the limestone, and resting on the gritty shale below it, is a layer of compressed limestone, very fine grained and of even texture, which when first exposed is of a warm gray color, almost a pale brown showing a decided umber tinge. It breaks with a subconchoidal fracture, and as it weathers, grows lighter and lighter in color as well as harder, until it has the appearance of chert even under the pocket lens. Unfortunately, this layer is only ten or twelve inches thick, for it is a valuable building stone, which was used in the construction of the Hoyt Library and the S. T. & H. Railroad Building in Saginaw. It is not saved at the quarry unless there is a special order for it. No seams or veins of flint (chert) were to be seen; nearly all concretions were of globular form.

During my first years of collecting, I often wondered at my failure to find large or long spear-points and other implements from the familiar chert, and in fact never have seen one over six inches long in any collection. The reason is simple, for the largest nodules are not often over six inches in diameter, and a quarryman who was employed there eight years told me that he had never seen one over eight inches through. My own collection, gathered from Indian village- and camp-sites, numbers perhaps a hundred specimens, from the perfect unbroken nodule to fragments showing unusual coloring, vugs, chalcedony cores, drusy cavities or agatized formation.

One almost perfect hemisphere is eight and a half inches across; another is in form, size and color a nearly perfect imitation of a baseball, or rather of a large tennis ball. The first one I ever picked up was of a perfect heart-shape, very much resembling a fair-sized pig's heart, even to the severed arteries at the top, and the woman in whose field I found it suggested that it was a petrified heart.

Vugs at the center of nodules are not infrequent, while solid chalcedony cores are quite common as well as vugs lined with beautiful botryoidal masses of that substance. I have others displaying masses of water-clear quartz crystals, the largest individual crystal not over a quarter of an inch in diameter. Rarely one finds an exquisitely banded gray and white agate, one or two specimens in my collection being unique in their delicate contrasting layers. Occasionally a small specimen of clouded gray agate has been found, and one of these had been worked into a lozenge shape by the red lapidary. These Bay Port nodules show little coloring in general, and I am inclined to believe that the occasional yellow and brown arrow-points and such things are largely from the Cass River locality, although further investigation may show that colored chert is produced from other outcrops.

On Section 5, Township of James, there is a space covering about two acres on each side of the north and south quarter-line, and north of the east and west quarter-line which is strewn with flakes and spalls of a yellow-brown chert approaching a jasper, and in some specimens well-deserving that designation. An occasional arrow-point or other object of the same material is sometimes picked up there, and I have two or three pieces showing brown or yellow chalcedony cores. It would seem that a canoe-load of these characteristic nodules had been worked up on this two acres, and I have found fine arrow-points of this material on village sites a mile or more away. It is sub-translucent, and the unpolished fragments have a waxy luster.

On this same section I found, several years ago, a cache of leaf-shaped blades, numbering nearly sixty. They were of the common chert, but showed ochery-yellow stains running through the mass of stone. In March of the present year (1927) I found half a mile to the west on a low sand knoll, where the wind had blown away the sand, a little pile of flakes of the same material and very easily identified by the unusual yellow stains, being the waste from the cache. Near at hand was a common hammerstone, I doubt not the one used in striking off the flakes from the nodules.

Very rarely an arrow-point or other article chipped from the sphalerite-impregnated chert will be found, and I have in my collection a very thin beautiful blade of peculiar form with tiny notches at one end, thus giving it the outline of a fish. Years ago, a cache of similarly shaped blades were figured by Harlan I. Smith as having been found at the Fraser Mound two and a half miles west of where I collected the one described. As these were too delicate and fragile for use as knives or spear-points, I presume they were intended to be keepsakes or were perhaps of totemic significance. The nodules from which these were formed were large, possibly elongated.

Many of the Bay Port nodules are of imitative forms, being pear-shaped, squash-shaped or egg-shaped, and one or two are of phallic appearance. Many contain fossils, particularly of insects, one slab in the collection being filled with organic remains. Most of these nodules appear to have been formed by the gradual filling up of cavities in the limestone by a process of growth by which the cavity was lined with siliceous material, gradually becoming more and more pure toward the center where the filling was completed with a chalcedony core. Others, however, would seem to have formed around an organic nucleus, which in some specimens has dissolved out, leaving a cast. One egg-shaped nodule has a hole running through its entire length, and appears as though it had grown around a twig, a root, or possibly even some member of an animal, such as a bone.

A large percentage of flint artifacts show the concretionary growth-rings, and tell the tale of *why* we do not find the huge blades that Flint Ridge produced, or the large hoes and spade-like forms from the vein-flint of Illinois.

In short, the Bay Port chert is characteristic for the Saginaw region, and we find arrow-points of it from the Straits to Jackson and from Manistee to Port Huron, the arrow-maker gathering his canoe-load of nodules from the Cass, from the shores of the Bay, from the islands; transporting them to the converging streams of Saginaw; burying them in wet places to keep them workable; from time to time drawing on his stock and working it up into leaf-shaped blades, again cached, and withdrawn as

needed to be notched and stemmed into the finished arrow-point: working the odd chips into scrapers for skin-dressing; occasionally chipping out some fantastic form or exercising his skill in the most delicate, dainty chipping in notches so fine and even that they seem almost machine-made, and running in some specimens to thirty or forty to the inch, and sometimes of almost needle-like sharpness of point, all with the crude tools of the Stone Age.

Turning now to the rarer materials, we find two sources of supply; one, the occasional pebble from river-bed, or bank, and the other, traffic with other regions or expeditions to them.

From the river-bed comes the infrequent arrow-point of red or blue or green jasper, the occasional spear or arrow of trachyte or scraper of quartzite with even a possibility of an occasional blade of lydian-stone, although it is probable that lydian-stone nearly always came from the south through trade. Sometimes a mass of chalcedony of beautiful tint and texture may be picked up, and we find chippings and fragments as well as the finished article, thus showing the manufacture of these gem-artifacts on the spot. Once in a while the collector's heart will be gladdened by an agate drill, perforator or arrow-point, and these too are sometimes found in the Saginaw country.

In Saginaw County itself, the Cass River from Cook's Grove at the edge of Bridgeport Township to the county line east, has at least four rapids or rifts where the river-bed is covered with boulders, while the Flint has a notable spot near the south county line, so notable, in fact, that the Indians themselves called it *Peonigoing*, "the place of stones." The Shiawassee, too, above Chesaning, formerly furnished its share of material, but these old rifts are now flooded by the two dams. On the Tittabawassee, there is a boulder bed a mile below Freeland.

Through trade or expeditions our Indian lapidary came into possession of the familiar Flint Ridge chalcedony, as well as the fine pink chert, or more properly, jasper, for it has all the attributes of jasper. This fine material occurred in nearly every quality, and I have seen collected here in this county a pink jasper blade ten and one-half inches long and about two inches

wide, as well as arrow-points so small and of so fine quality as to be readily classed with the "gem" points from Oregon and other western localities. Our Michigan chert is characterized by its concentric rings, sometimes very distinct, while the Flint Ridge material is massive, lying in beds or layers. Rarely do we find any flint of lower Michigan origin that is not nodular, although occasionally a specimen is picked up that would seem to have originated in a vein or seam, but usually a close examination will reveal its nodular character.

I have one very good specimen of this character, which has been polished on one face, bringing out the clouded agate formation. From the Satchell Indian village site in Frankenmuth Township, I collected a fair-sized agate of poor quality which is in contrast to the specimen last mentioned, as its concretionary form is very plainly manifest.

Occasionally I have picked up jasper pebbles, mostly from disintegrated "pudding-stone," but sometimes they are found in the gravel or among the boulders in the river-beds of larger size and on these it seems that occasionally some Indian artificer tried his skill and fashioned a beautiful point or drill, almost always small or of medium size.

This gem material is frequently of such beauty that stones suitable for ring and pin settings can be cut from it, and I have had some twenty or thirty such prepared, including jasper, agate, chalcedony, milky quartz and lydian-stone. Some of these were seen by a prominent local jeweler and his wife, and they were so struck by the unique beauty of two lydian-stone gems, one cut cabochon, the other oval table, that they begged a piece of the raw material and had it cut into a pair of similar stones, and the wife now wears one of them in a fine setting in preference to more expensive jewels. A gray agate of unusual markings in this lot is of interest as showing the vast difference between the rough and the polished stone. People seeing them often exclaim, "Is it possible that such a pretty stone can be cut from a piece of common rock?" They do not know that it is *not* common, but is carefully selected from a thousand pieces of stone which *is* common, and therefore it has a value because it is scarce.

A carefully selected collection of Indian "relics" will usually contain a number of pipes both of pottery and stone, but the "collector" will usually be looking for "calumets," as he calls them, and usually we will find that he has specimens of very recent manufacture, and ornamented in a way that no primitive Indian ever thought of. Sometimes we see them with mosaic bands and figures of metallic lead of a slightly more remote date, but still showing plainly white influence and white metallurgy. The pipes that interest the archaeologist are those of primitive culture, and occasionally a red or mottled pipe from those noted quarries in Minnesota is picked up in the Saginaw district, and rarely a piece of the raw material. I have one such piece in my own collection, bearing the marks of the primitive tool upon it; also a tiny figure of a beaver two and one-half inches long, one-half inch wide and one-quarter inch thick, with a hole drilled its whole length, a rare little specimen. This stone and this little figurine were very likely secured on an expedition, although perhaps this esteemed material was occasionally obtained through trade.

I have mentioned the fine-grained, clayey limestone from the Cass River used for pipes, and this stream also furnished a sandstone of two or three grades which was used for the same purpose, my collection containing several specimens, one of them a sort of pebbly or conglomorate sand-stone with scattered small pebbles. The Indian pipe-maker well understood his materials, and used only those that would not flake off or crack under the unequal heat or expansion to which they were subjected.

We come now to an interesting section of Indian stone-work, that of tablets, gorgets, bird and animal figures and so-called ceremonials. Here we find as raw material the favorite green banded slate, red and purple slate, black slate and even fine-grained sandstone as well as rarely harder and coarser stones. I have in my collection articles of this class running from the roughed-out oval tablet or gorget formed by the chipping process as well as the hard slate shaped by pecking, to the completed, neatly polished and perforated figure of an otter, conventionalized it is true, but indicating an exceedingly skilled workman

who knew his trade. Most of this material was gathered from the rivers; it is a contribution from the Ice Age dropped near the present surface, and uncovered by the wearing waters of the several streams, or possibly in the case of the black slate, occasionally found in place near the few outcrops of the Carboniferous formations. I have collected specimens of almost every variety mentioned on the rifts of the Cass River or other streams, and one specimen in my collection, a boulder weighing several pounds, almost approaches jasper in hardness, being, I should judge without a perfect test, about 6 on Moh's scale. It is beautifully banded in two shades of green together with a red brown. It is also of interest as showing the effects of the great heat by which it has reached its present nature and appearance.

Occasionally harder stone was used for animal figures, and one in my possession is that of a goose, worked from some fine-grained stone of hard texture, perhaps a granite or gneiss. Another is a large roughed-out bird or animal figure of similar hard stone.

We find sandstone in various degrees of coarseness for rough-grinding and sharpening axes and celts, as well as polishing and finishing pieces of slate, almost invariably black, for sharpening and polishing bone needles and awls, and sandstone rubbers for smoothing arrow-shafts and other articles of wood. This sandstone outcropped in several places as has been already noted, and, when frozen into the ice, on the Cass River, was not infrequently brought down in the spring by flood-waters, which often transport stones for miles in this manner. I have picked up small slabs of the sandstone that forms the bed of that stream near Cass City perhaps thirty miles below.

The materials for axes, mauls, chisels, adzes and other weapons and tools worked by pecking was plentifully supplied from the boulder-beds already mentioned, and syenite, granite, gneiss or, rarely, other metamorphic rock such as trachyte. Some beautiful specimens fashioned from fine-grained stone of uniform texture, and others showing hornblende crystals, and still others discovering crystals of feldspar, are to be found, and rarely do we see an implement of this kind that does not exhibit the qualities most needed, such as hardness, toughness or tenacity. A tool

for which a sharp edge was required called for qualities different from those of one that was used merely for battering.

Small ornaments, such as beads of aboriginal manufacture, are seldom found in this district, but rarely a hematite bead or one of slate may turn up. The hematite was of course largely from trade or brought south by expeditions to our Upper Peninsula, but some years ago the writer found what to him was a rarity, a small bit of iron ore which was strongly attracted to the magnet. This was collected on a sand knoll, an ancient village site where I have secured many pieces. The sand is filled with flint flakes and other remains of the ancient dweller, but aside from what has been brought by the hand of man is utterly barren of stones, so I was well satisfied that this was a former possession of some Red Man, and treasured for the same reason that I treasured it. A few years later I found a boulder-bed about a half-mile long, three or four miles farther upstream, and to my surprise, discovered that there were numerous pieces of similar ore, some of them weighing many pounds, scattered among the other boulders. Here was likely the source of my bit of iron. This is the boulder-bed mentioned as being on the Tittabawassee River below Freeland. Another thing that seemed curious to me was the fact that large boulders lying in place in the clay were deeply striated, all in the same direction. Perhaps some geologist may explain. Striations are common enough, but to see loose boulders thus striated seems odd. They appeared to follow about the same contour line under the high bank.

I have frequently collected masses of fossil coral, both from village sites and from river beds, and have perhaps twenty or twenty-five varieties, but I have never observed a single ornament made from this material. The most beautiful specimen I have ever seen, I owe to some Indian long dead. The high waters of spring washed out an old wigwam site, and along with other articles I secured this coral. The Indians were as much interested in the curiosities that fell under their observation as we are, and I have a fossil shark's tooth, a piece of rose quartz, a siliceous stalactite, queer concretions, and other articles taken from graves or village sites that were undoubtedly held with as

much interest as I now hold them. A race of men given to contemplation and thought to such an extent as our Indians were could not but observe the wonders and beauties of Nature, and in her works, they saw and marvelled at the strange and wonderful, and admired and delighted in the beautiful.

Could we, in the present generation, get a little away from the material, occasionally, it would well be worth our while. Here we have a man who loves the wild flowers and studies them and revels in gardens of Nature's own planting; here is another whose recreation is found in those winged flowers, the moths and butterflies; still another tells us of those flitting and fleeting creatures that come to us in the spring and depart from us in the autumn, the birds; still another studies the rocks and "the Everlasting Hills," and "follows Nature to her most retired apartments"; another studies with the deepest satisfaction those wonderful, yes, marvellous crystallized and aggregated forms called precious stones, while some poor souls like myself content themselves with those odds and ends that a more or less mysterious people have left behind, and find a pleasure and an occasional "thrill" in being called either archaeologists, professional or amateur, by a small part of the community, but more often referred to as crack-brained bone-hunters by the hard-hearted general public.

It is not well to live in the clouds all the time; neither is it well to live in the dust. There may be a happy medium, but I at least have not found it, for in the necessities of the case, we must feed, house and clothe ourselves and families, and unless we are professional men following certain lines, we must go to the dust once in a while, for where does one find corn or beans growing in the clouds? It is well thus, and no man, though ever so poor, need lack in sky overhead, or give up his dreams and his joy in living.

Saginaw, Michigan

A METHOD OF CERAMIC DESCRIPTION

CARL E. GUTHE

CERAMIC specimens form an important group of material, not only in the detailed study of the archaeology of a small restricted area, but also in the larger problems brought out by the study of diffusion of extinct culture traits. Yet little attention has been given to the special problems incident to the proper, accurate description of ceramic specimens. In order that published material on regional ceramics may prove of the greatest value, a form of description must be adopted which treats of all, and not merely of some of the characters of pottery, and which is, within the limits of the problem, comprehensible to investigators in related fields.

Since pottery making is a culture complex, it is, therefore, incapable of description by hard and fast rules, similar to those used by systematists in biology. It is possible, however, to formulate definite principles of treatment, based upon the major characters of pottery, which are common to all things made of clay. Such a study is essentially an objective one, in which all the factors considered exist within the specimen itself, isolated from its cultural and environmental surroundings. The problem before us, then, is that of presenting a broad, practical outline of the way in which a given specimen or group of specimens should be described in order that the description may serve, with or without an accompanying photograph, adequately to reproduce in the mind of the specialist reading it a clear and definite mental image. This problem has four distinct aspects, based upon the four primary characters of ceramic material, which are paste, surface finish, decoration and form.

THE PASTE

There are four attributes of the paste or body which must be taken into consideration in rendering an adequate description.

The most obvious of these is its composition, the clay proper and the tempering material or grog. In some instances chemical analyses are advisable. In those classes of pottery in which the temper can be differentiated from the clay itself, special attention should be given the tempering material used, its degree of coarseness, and its relative quantity in proportion to the clay.

The second attribute of paste is its texture. The cross-section of a specimen discloses at once the degree of thoroughness with which the potter treated the paste before construction. In crude pottery the paste usually has an irregular texture, with varying degrees of fineness not only within a single cross-section, but also in different parts of the same piece. In the technically more advanced pieces, levigation causes a uniform, fine texture.

The third attribute of the paste is its hardness, which depends primarily upon the degree of heat to which the specimen has been exposed. It is, however, impossible to arrange a definite table of hardness based upon definite degrees of firing, for different pastes react differently to the process. Hardness is sometimes described by the ease with which the paste can be scratched with a knife. Mr. Kershaw describes a method based upon the ability of the paste to absorb a drop of water.

The fourth and most variable attribute is color. The composition of the paste determines the color in a general way, though the firing also has a strong effect upon it. Variation of distribution or quantity of the fire may cause the color to vary over areas of the piece, or in proportion to its position in the cross-section. Again, in coated vessels, exposure to the naked flame may completely change the paste color.

THE SURFACE FINISH

The term "surface finish" refers to that dominant feature of a ceramic specimen which is the result of a uniform treatment of the major part of its surface. It is the character upon which the first rough classification of material is usually made. Because of the interpretation frequently given the words "decoration" and "ornamentation" to include all embellishments of the paste itself, the real value of the surface finish has not been appreciated.

This second character is not the result of a step in construction but rather that of a complex technique. The first stages of the treatment of the surface may occur before the specimen loses its plasticity, while the last stage may be the ultimate one in construction.

There are two major forms of surface finish. The first is the result of manipulation only of the surface of the paste, by processes known as smoothing, scraping and polishing. The second is due to the coating of the paste with a variety of substances. If a wash of clay is used it is called slipping. Or again a non-mineral substance, such as various tree-gums, wax, oil, and the like, may be used. In certain great areas types of glass are used, which have been designated alkaline, salt, lead, or felspathic glazes, depending upon the character of their principal constituents.

Except in the most simple wares, the surface finish is the result of a combination of treatments. Most surfaces which have been coated have first been smoothed or scraped. Likewise the coating of the surface may be composed of several layers, not only of different colors, but also of different materials. In describing the surface finish of a specimen which has been coated, four attributes must be taken into account. The first of these is the substance used, the second the color, the third the texture, and the last the thickness of the coat.

The surface finish is also affected by a series of factors entirely distinct from those of construction. These are the result of the treatment after completion, in which use, time or weather may cause the addition of material, discoloration, change in texture, flaking, or complete decomposition and disintegration.

In view of the fact that the problems inherent in the study of the surface finish are multiple and quite distinct from decoration, it is advisable to treat it as a ceramic character distinct from paste, as well as from decoration and form.

THE DECORATION

The third of the ceramic characters is the decoration, the problems of which are of two kinds, those which deal with deco-

rative design, and those which deal with decorative technique. An adequate study of design must be based upon an interpretative consideration of the elements and motifs, which are so varied that they constitute the special problem of investigators working in the restricted ceramic areas.

Because of the limitations of the medium involved, the processes or technique by which those designs may be associated with ceramic material may be classified under a small number of general methods of application, which also fall naturally into two groups. The first of these is that in which minor alterations occur in the surface which is to be decorated, by use of a series of processes which result in incised, engraved and pressed patterns. The second is that in which the design is formed by addition of material to the surface. There are four general processes in this group. The first, and most widely spread, is the application of paint. The second is the application of enamel, which is largely confined to glazed surfaces. The third is by the addition of paste in small quantities in such a manner as to form a raised or applied pattern. The fourth is that of encrusting the surface with fragments of shell, wood, various metals and similar materials. All these processes may be further subdivided by recognition of refinements of technique.

The decoration of a specimen is usually the result of a combination of two or more of the processes mentioned. Similarly, it may be associated with the surface finish in a variety of ways. The design may occur over or under the various coatings, and the decoration may be done at almost any stage in the construction.

The description of the design alone, while properly occupying the major part of a report on a special ceramic group, does not constitute an adequate discussion of the decoration. The various techniques used, their relationships to one another and to the surface finish, must also be adequately described.

THE FORM

The fourth and final ceramic character is the form, in which the shapes encountered are myriad. They may be roughly and

inadequately grouped as containers, effigies, and objects of primarily utilitarian or aesthetic nature not included in the first two groups. In spite of the great variety of forms it is possible to indicate certain aspects of this character which must be treated in an adequate description. The first consideration is that of the methods by which forms are achieved. These are three: the use of the wheel, the use of moulds, and the dexterity of the potter's hand alone.

In the discussion which follows containers only are considered, because they form the bulk of comparative material, and because an attempt to include all forms would merely confuse the issue. Emphasis must be placed on the importance of grouping material by criteria of shape alone. An attempt to use related and highly suggestive criteria, such as use, size and functional additions, will do more harm than good.

The most rational method of studying form is by means of cross-sections. But a single vertical cross-section through the center of the vessel is not always sufficient. The possibilities of parallel sections made along two planes at right angles to each other must be taken into account.

By use of the cross-section method it becomes possible to break up the form into its four component parts, which are body shape, basal shape, oral shape and the shape of the secondary features. By body shape is meant the form of that part of the vessel upon which its fundamental shape depends, which in cross-section consists of a uniform curve or group of curves tending to form a simple geometric figure. The basal and the oral shapes are those which result from the specialized treatment of the lower part and the mouth of the vessel, respectively. Secondary features are those which result from the application of large amounts of paste or other materials sufficient essentially to alter or hide the body shape in restricted areas of the surface. The differentiations just made are based upon the lack of harmony existing between the major curves of the four parts, when viewed in cross-section. The actual meeting point of two of these parts is not likely to be a line. It is usually a junction zone, which may be defined as that area of the surface in which the major

curves of two adjacent form parts have been altered to permit the gradual merging of the surface of one into that of the other.

If, therefore, the study of this fourth ceramic character is undertaken with an appreciation of the essential individuality and the possible combinations of these four component parts of form, it is believed that the difficulties of classification by this character will be diminished.

Finally, the dimensions of a specimen should be included in a complete description. Measurements should be taken not only of the general size, but also of the cross-section of the body wall. The figures given should be the average of a series of measurements. In addition to greatest height and width of the vessel, it is often advisable to give the dimensions of each of the component parts of the form.

WARES AND STYLES

The discussion of the principles of ceramic description which has just been completed would be largely valueless without a consideration of the connotation of such terms as "wares," "styles," and "types," which unfortunately have a vagueness of definition, resulting from the lax and indiscriminate manner in which they have been used. These terms, if they are to have real value, must refer to groups which combine several of the attributes just discussed. The word "ware" refers to fundamental similarity, the word "style" to superficial similarity, and the word "type" to a large generic group. On this basis the following definitions are suggested.

A ware is a ceramic group in which all attributes of the paste and the surface finish remain constant. A style of decoration is a ceramic group in which decorative design and technique both remain constant. A style of form is a ceramic group in which the form as a whole remains essentially constant, and is distinguished by some outstanding feature. A type is a ceramic group wherein the similarity is a generic one of all four characters caused by the entire pottery complex of the designated culture group. The scope of these definitions may be controlled by the use of delimiting adjectives. It is to be noted that the first

three take no account of time or space, and are mutually exclusive, thereby permitting a study of distribution both geographically and stratigraphically without a confusion of terms.

CONCLUSION

The fundamental purpose of this paper is an attempt to evolve a general scheme of ceramic description and classification which might serve to unify ceramic method and improve published descriptions. While the method advanced is neither detailed nor perfect, it is presented in the hope that it may stimulate discussion and research in this rather neglected field of general ceramic method and terminology, and thereby serve to increase the value of ceramics in the study of culture development.

University of Michigan

INDIAN CORN CULTURE IN MICHIGAN

WILBERT B. HINSDALE

THE Indians were extensive cultivators of the soil. Many different tribes were agriculturists. What they cultivated besides corn does not particularly enter into the subject of this dissertation; but bean, squash and pumpkin culture received attention from them. Smoking was a universal ceremony. Tobacco, therefore, must have been one of their garden and field products. It is reported that in Eaton County, where the city of Charlotte now stands, was an extensive corn-field.[1] Large corn-fields are referred to by C. Popleton, in Oakland County.[2] A more specific reference to the same county is that, in Avon Township, the hills were arranged in rows and the stones had been picked from the surface of the ground.[3]

There was, a few years ago, evidence of old planting grounds of five or six acres not far from St. Ignace. Notes given me by Professor J. B. Steere, upon Montcalm County, state that in Section 9, Cato Township, just west of Tamarack Lake, in passing through in 1865, he noticed numerous little mounds, perhaps three feet apart, a foot and a half in diameter and five or six inches high. There was an acre or more of them. Several burial mounds were near by from eight to ten feet in diameter and from three to five feet high. On still higher ground were a number of pits several feet in depth, which he thought must have been corn pits.

In Macomb County, six and one-half miles northeast of Romeo, are still discernible a few acres of old Indian corn-fields, described to me by Dr. R. M. Greenshields. In Barry County,

[1] Edward A. Post, *Michigan Pioneer Collections*, 3:379.
[2] *Michigan Pioneer Collections*, 14: 516.
[3] *History of Oakland County*, 1877, p. 135.

on the prairies along the Thornapple River, when the land was first "taken up," were several acres of corn-hills, "not in rows, but hap-hazardly." [4]

In Ingham County there were many Indian planting grounds. One was at Okemos. Another, of ten or fifteen acres, was on the south branch of Cedar River where it is crossed by the Grand River Trail, west of Williamston.[5]

Kent County had numerous and extensive Indian corn-fields. In Ada Township, at the mouth of the Thornapple, upon both sides of the river, were many acres of old corn-hills. On a high hill, south from these, were numbers of pits. There were also many acres of Indian corn-fields on the west side of the river where Grand Rapids now stands.[6]

During the past two or three years, members of the Museum staff of the University of Michigan have located old Indian corn-fields in various parts of the state: one in Manistee County, Brown Township, northwest quarter, Section 30, along the bluff of Manistee River; another in Kalkaska County, Clear Water Township, Section 8.

Ionia County was a prehistoric agricultural district. In Pewamo Township, a half-mile north of Pewamo village, was a village site and large corn-field. Very many other fields were scattered along the Grand, Maple, Lookingglass and Flat rivers, but the information is vague as to the sections of land upon which they were found.

In Kalamazoo County, Portage Township, Mr. Edward J. Stevens gives a record of "A tract three or four miles square with greater length northwest to southeast, many of them very regularly laid out."

In nearly every part of Livingston County there "were old 'Indian Fields' in which they would plant their seeds for many successive years." [7]

Mr. Fred Dustin of Saginaw, a very accurate observer and

[4] Charles A. Weissert, *Michigan Historical Collections*, 38: 662.
[5] Adams, *Pioneer History, Ingham Co.*, p. 481.
[6] *History of Kent Co., Michigan*, 1881, p. 813.
[7] *History of Livingston Co., Michigan*, 1880, p. 10.

the best informed man upon the archaeology and ethnology of the Saginaw Valley, under date of November 26, 1926, gives the location of thirteen corn-fields, "very ancient," the most of them in the fertile valleys of the Saginaw, Tittabawassee, Cass, Shiawassee and Flint rivers. One "of about one hundred acres" was on Section 33, Taymouth Township, east side of Flint River near mouth of Pine River. These sites are now all under cultivation as the soil upon which they were situated, being very fertile, was the first to be taken up by white farmers, in the thirties, who have not allowed a single vestige of an Indian corn-hill to remain, but Mr. Dustin's records are thoroughly dependable and verified. He has the only specimens of "some prehistoric corn cobs" from the state that are known to the writer. These charred cobs were "washed out by high water from some three or four feet below the surface, last spring" (1926).

The Indians cultivated a field in the northwest quarter of Section 12, Scio Township, Washtenaw County. This plat was by the side of the Huron River and, seventy-five years ago, showed unmistakable evidence of having been tilled for a long time. There were distinct signs of a very old village upon this tract until it was submerged by the damming of the river for power purposes, fifteen years ago.

Dr. M. L. Leach refers to "gardens of no mean extent" in the Grand Traverse region. Some were in the vicinity of Harbor Springs, others upon the peninsula between the two arms of Grand Traverse Bay, but his descriptions are indefinite as to exact locations.[8] The late Mr. L. D. Watkins, who took a lively interest in pioneer and local Indian history, in a manuscript left by him says: "There was not a township in southern Michigan without one or more trails with camping grounds and corn-fields."

Blois makes the statement, "The remains of ancient corn-fields are of frequent occurrence (1838) in all those parts of Michigan previously occupied by the Indian." [9]

According to a map (1840) to accompany the report of Cap-

[8] *History of Grand Traverse Region*, 1883.
[9] *Gazetteer of Michigan*, p. 173.

tain C. D. Kram on the boundary between Michigan and Wisconsin, there were extensive planting grounds upon the Menominee River below Lac Vieux Desert.

Bela Hubbard, describing a trip he took down the Shiawassee River in 1837, when the natives had felt little of the fatal spell which falls upon them with the very beginnings of white settlements, gives the following memorandum: "Many of the Indian clearings stretched for several continuous miles, and many acres bordering the river were covered with luxuriant maize — the chief cultivated food of the natives." He refers also to caches for hiding provisions. At the time of this observation Hubbard was somewhere in Shiawassee County below Byron and above Corunna.[10]

Schoolcraft, writing about Mackinac Island in 1827, said: "Old green fields appeared in spots, which have been formerly cultivated by Indians."[11] *The Journal and Michigan Advertiser*, November 9, 1831, published in Detroit, reported: "The largest corn I ever saw was raised on these prairies," referring to lands adjoining the Grand River, where the correspondent claimed to have resided for ten years.[12] Friendly Indians settled about all the frontier forts and missions and had their planting grounds for corn.[13]

Were one to take the time to survey the lands of the state that have not come under the plow, to look into every old newspaper file and "Pioneer Record," and to have personal interviews with "old timers," making inquiry about Indian planting grounds and to chart the results in red upon a blank outline map, he would be greatly surprised to see the white of his map turn red.

From September 22 to 26, 1926, I visited Haynes Township, Alcona County, and found on Sections 22 and 27 many acres of old corn-hills (see Fig. 1). The quarter-section post on the boundary of these two sections is about in the center of the tract. The

[10] *Memorials of a Half-Century*, p. 70.
[11] *Mississippi*, p. 59.
[12] Fuller, *Economic and Social Beginnings of Michigan*, p. 415.
[13] Lanman, *History of Michigan*, 1852, p. 62.

FIGURE 1
Old Indian corn-field still to be seen in Haynes Township, Alcona County, Michigan

hills showed very distinctly among the wild strawberry vines and grasses of a cow pasture, which comprised at least seventy-five acres. In other parts of this large pasture field corn patches were found. By actual measurement, with surveyor's tape, one block of the hills figured out eighteen and one-half acres. In all, there are at least twenty-five acres of distinct hills. An old settler, Mr. William Armstrong, stated that forty years ago he plowed up twenty acres of Indian corn-fields upon the same section line, Section 28. The hills, which are conical, average two feet in diameter at the base and from six to twelve inches high. The distance from hill to hill is about four feet. One small area, which had been laid out with unusual regularity, measured four feet and four inches from hill to hill both ways. The usual alignment is quite irregular; the irregularity in the rows is due in part, no doubt, to the necessity of avoiding trees and obstructions that were not leveled down.

I was informed by old lumbermen, still residing in the locality, that they had seen just as extensive and exactly similar fields elsewhere in that and adjoining counties. This crude agriculture flourished at the time when the Indian was a hunter and before he had been much, if at all, influenced by white men.

The finding of unusual numbers of stone artifacts lends force to the belief that this region, which is skirted upon the north by a branch of Black River and sixty or more rods to the south by a range of low gravelly hills, was inhabited by Indians still in their native culture-stages. The pictures of Indian corn-hills in Massachusetts, given by Dr. Wilder, very accurately resemble those in Michigan just described.[14]

It would appear that each squaw who was the "head of a family" had her own garden, and adjoining it was the garden or small field of another. It is a question whether the tilling of the soil was coöperative; that is, carried on by all the community in common, or whether each family, whose chief gardener was of course the woman, had its own allotment. The latter conjecture is the more probable, although in some sections of the country there was coöperative gardening, and sometimes the vigorous

[14] *American Anthropologist*, July–Sept., 1920, p. 212.

men helped a little. Old men, retired from aggressive life, and children assisted the women. It is not likely that an area as large as a hundred acres was under cultivation at the same time. Fields would, however, sometimes lie fallow for a year or more; there is no evidence upon the ground to indicate how it was. The land has never been plowed or the striking features now observable would have been completely obliterated. There are numerous pine stumps, the remains of trees that were lumbered forty years ago. Stumps of hardwood are more common. The hardwood was removed twenty-five years ago. The pines upon this place were large, but there were wide openings among them. The pine openings were filled in considerably with maple and birch. I am of the opinion that this hardwood has made its growth since the Indians abandoned the corn-field. At any rate, the shade was not so dense as to prevent a fair growth of corn. As stated, the ground is completely turfed over and overgrown with low vegetation. Two years ago the fields were entirely burned over. After the fire had cleared up the ground, the corn-hills were strikingly conspicuous. In the early spring after the snow has packed down the previous year's herbage, the irregular rows can be observed for a distance of forty rods. In September, they were not discernible for more than half that distance. A considerable number of artifacts, such as farmers call "flints," "skinning stones," and hatchets have been gathered, many of which are preserved in small collections in the vicinity. No doubt village sites and burial grounds will be found if the land comes under cultivation. These plats of corn-hills are said, by men who assisted in the clearing off of the timber, to have had the same appearance among the trees that they now have among the stumps.

The Ottoways of L'Arbre Croche raised corn to supply the canoe men at Michilemackinac, but that was after they had adopted a good many traits from the mission that had been established at their village.[15] They knew how to raise corn and the marketing idea was not new to them.

[15] Alexander Henry, *Travels and Adventures in Canada, and the Indian Territories, between the Years 1760, and 1776.*

The amount of corn that was raised in prehistoric times cannot be estimated by the amounts raised after the chroniclers began to make note of things, for then different conditions obtained and primitive culture had been considerably changed, but trade in some form is essential to community life or at least to the maintenance of continuous populations. Corn must have been a commodity that was exchangeable with distant tribes and, where it was raised, produced with the intention of bartering. Short crops and crop failures, due to many causes, affected Indian welfare the same as they affect farmers of the present time. Years of plenty, years of just enough, years of no yield, had their effects, only more keenly, the same as now.

Indians have the reputation of being profligate, consuming to excess in times of surfeit, suffering to starvation in years of famine. How far this notion would have been borne out by the facts, could they have been observed, it is difficult to say. But they certainly had the idea, which is called instinct with lower animals, of harvesting and hoarding; hence they had places and constructed means for the preservation of supplies.

There is much evidence to substantiate the contention that the Algonquins subsisted more upon vegetable foods than upon the results of the hunt. In Michigan, corn was the staple. Around Green Bay and in the northwestern part of the state, wild rice, to the amount of several bushels per family, was gathered annually.[16]

For a hundred years after the Great Lakes districts were traversed by French and English traders — and every trader and traveler was a fur-dealer — hunting fur-bearing animals was encouraged by all possible means. The Indians began to hunt for gain. Usually a bundle of skins was exchanged for enough watered whisky for a two-days' carousal. As the collection of skins increased, and the consumption of the byproducts of trapping, the flesh of captured animals, also increased, the raising of corn received less attention as a necessary employment. White contact, for a time, made the tribes greater hunters than they were in the primitive state.

[16] Jenks, *Report of the American Bureau of Ethnology*, 19, Part II, 1013.

I have not made any reference, in mentioning places where the Indians grew corn, to the "garden beds" that Bela Hubbard, Schoolcraft and several other writers upon the antiquities of Michigan have described, because there is doubt if they were corn-fields. If they were, they show very distinctive types of tillage from the conical hills.

The Indians built the first corn-cribs. Cribs among the southern Indians were built upon posts, of poles, bark, intertwined twigs, and small sticks, which are said to have been plastered over. Cyrus Thomas says: "It is from the southern Indians that the farmers of today derived the method of constructing cribs on posts." [17] Bailey [18] quotes from Pickering's *Chronological History of Plants*: "About 1002 A.D. Thornwald, brother of Lief, wintered in Vineland and on an island far westward, saw a wooden crib for corn." The common farm cribs, built upon "stilts" or posts so that rats and mice may be more easily prevented from doing damage, are copies. There were no common rats and house mice here before the whites introduced them, but chipmunks, field mice, gophers, and other small native rodents could do much damage to stored grain and goods.

The natives of this part of the country stored a considerable part of their corn in pits in the ground. They also, when absent from their usual haunts, secreted their belongings in similar caches to prevent their being stolen. "It is quite a part of an Indian's code of morals not to steal from his friends, but it is quite equally a virtue to steal from his enemies." [19] Ground storage would not appear to be a hindrance to vermin. Caleb Atwater says, "Further . . . they often buried rice [wild rice] and maize in the ground to keep it from being stolen." He further adds, "Ottoways buried in ground granaries in birch boxes." [20]

The most common evidence of Indian work in the ground to be found in Michigan, whether mound, embankment or other

[17] *Report of the American Bureau of Ethnology*, 12: 619.
[18] *Cyclopedia of American Agriculture*, 2: 404.
[19] Jenks, *Report of the American Bureau of Ethnology*, 19, Part II, 1071.
[20] *Indians*, p. 102.

diggings, unless it be burial graves, is pit holes. They are found in great numbers in the vicinity of the old corn-fields just described, as well as in other parts of the state. If they were mostly, as observers generally contend, for the purpose of corn storage, they may be taken as a guide to the distribution of corn culture and would indicate, as stated before, its very extensive distribution. On a knoll northeast of the fields in Haynes Township, Alcona County, and practically adjoining, are seven pits arranged in a circle twenty feet across. In the center of the circle is an old fire-place. Two of the pits were cleared out with great care. They were both of the same dimensions and of identical construction. Across the top of the pits it is seven feet. The side walls are five feet, going down into the gravel perpendicularly. The pits are flat upon the bottom with a smaller pit in the center eight inches in diameter and twelve inches deep. They contain fragments of decayed and charred wood and ashes. Other pits were found haphazard over the clearing, which comprised at least one hundred acres. Charlevoix, writing from River St. Joseph, August 16, 1721, gives the following description of the Indians' treatment of corn in that section of the state: "Their corn and other fruits are preserved in receptories, which they dig in the ground and which are lined with large pieces of bark. Some of them leave the maize in the ear . . . and hang them on poles over the entry of their cabins. Others thresh it out and lay it up in large baskets of bark, bored on all sides to hinder it from heating: but, when they are obliged to be from home for any time or when they apprehend some irruption of the enemy, they make great concealments under ground where these sorts of grain are exceedingly well preserved." [21] A note by L. P. Kellogg, the editor of Charlevoix's Journal, says: "The process of making these hiding places was an interesting one. The white hunter soon learned it from the Indians and adopted it to preserve furs as well as provisions. The hunter's term for these hiding places was 'cache.'"

Alexander Henry, upon the Missouri River near Knife River, North Dakota, wrote (1806), referring to the Mandams: "It is

[21] Charlevoix, *Journal of a Voyage to North America*, II: 112–113.

customary in the fall, after harvest when the grain is well-dried in the sun, to take it off the cob, and deposit it in deep pits about the villages. These holes are about eight feet deep; the mouth is just wide enough for a person to descend, but the inside is hollowed out to any size and the bottom and sides are well-lined with dry straw. Such caches contain from twenty to thirty bushels of corn and beans, which are thrown in loose and covered over with straw and earth. . . . Grain stored in this way will keep for several years without injury. . . . So numerous about the villages are these pits . . . that it is really dangerous for a stranger to stir about after dark, as the natives never take the precaution to cover them over when empty." [22]

In some places, pits seem to show a degree of studious arrangement upon the part of their diggers. Reference has been made to a circular arrangement in Alcona County. In another location, in the same county and township, to the northeast and a mile from the shore of Lake Huron, is an arrangement of pits on the top of a hill in three rows so dug that in the middle row the pits come midway between or alternate with those of the other rows. The same pattern of pits is to be observed upon Section 35, Lincoln Township, Isabella County. Mr. G. W. Beever of Alcona County says he can locate over a hundred pits in Harrisville Township, which is immediately south of Haynes.

Probably no plant had a wider distribution upon the continent than corn. This is certainly true of domesticated plants. Nearly all the tribes in the territory now called United States, with the possible exception of some of those living west of the Rocky Mountains, cultivated it more or less, and more consumed corn than raised it, because non-producers are known to have procured it by trade.

General Sullivan and his officers, in their expedition against the Iroquois in the autumn of 1779, report destroying immense quantities of the Indians' corn. One report says about 1,200,000 bushels, another, 160,000 bushels, "with a vast quantity of vegetables of every kind." These reports will not stand cold verifi-

[22] *The Manuscript Journals of Alexander Henry and of David Thompson*, edited by Elliott Coues, p. 360.

cations by arithmetic and counter checking. It would require a "bin" 114 feet long, 114 feet wide and 114 feet high, or a crib 8 feet wide, 12 feet high and 2.95 miles long to hold all the corn Sullivan claims to have destroyed. Another big yarn or the same yarn about quantities of corn stored by the Indians in Seneca County, New York, is given by the Marquis De Noville, who claims to have destroyed in 1687 the identical number of bushels as reported by General Sullivan eighty-two years later. Sullivan's command no doubt did find and destroy enough of the grain to establish the fact that the New York Indians cultivated corn extensively and intensively.[23]

Morgan says corn was ever the staple food of the Iroquois which they preserved with husks braided together, and shelled and stored in bark barrels. "They excavate a pit, make a bark bottom and sides and having deposited their corn within it, a bark roof, water tight, was constructed over it and the whole covered up with earth." [24]

The agricultural is above the hunter stage of humanity. The soil could not be tilled by people who were perpetual wanderers in pursuit of game. There are two times in the year when planters have to be upon or near their fields. One is at planting, the other at harvest time. While cultivation of the crop after planting was crude, in order to obtain much of a yield, there must have been hoeing and weeding. There were a great many animals and birds that preyed upon the fields, some to dig up the seeds, others to eat the growing and matured grain. The scarecrow, traps, and other devices to keep away robbers were parts of the system of cultivation. The corn growers were more or less sedentary with fixed abodes, but they could leave the fields after gathering and storing the grain for the next season's use and go upon the autumnal hunt.

Nearly every tribe had its hunting ground, which friends were ready to respect, but tribal enemies had to be watched and

[23] *Journals of the Military Expedition against the Six Nations;* also A. C. Parker, *Iroquois Uses of Maize, etc.; Educational Dept. Bull. of N. Y.*, Nov. 1, 1910; *Documentary History of N. Y.*, 1: 238.

[24] *League of the Iroquois*, I: 311.

fought away. Poaching and robbing led to many a bloody fight and, in fact, were the causes of extensive wars. Sometimes the hunting places were far distant from the summer abodes and necessitated long tramps over the trails and the establishment of temporary camps or villages. The accoutrements of the chase and lodges had to be transported wearily by canoe or on foot or both ways. The trails were retraced after the hunt, frequently for maple sugar making before corn planting.

With all their crude but necessary farming, the Indians of the timber belts and the majority of those upon plains and mountains were in the hunter stages of culture, but were not so much given to roving as is generally supposed to have been the case. In the dense pine and hemlock woods, it is not probable there was any cultivation. A very large part of the pine land, since lumbering, is not sufficiently fertile to produce paying field crops. Hundreds of white farmers have failed to make livings upon them, have permitted their titles to lapse for non-payment of taxes, and are moving away. The openings, prairies, hardwood belts and river valleys are productive, and the distribution of corn culture over the state is about the same for the white as it was for the red man.

After centuries of unconscious selection, the Indians had developed varieties of corn with wonderful adaptation to the climatic condition in which they were grown. In the southwest among the Pueblos there were drought-resisting kinds. In the north, where the seasons were short, there were varieties that matured early after planting. There were kinds that would do well in the half-shade of open woods. It made no difference to the Indian, as it does to the white farmer, if the stalks or "fodder" were frostbitten. The kernels of corn are ripe while the foliage is yet quite green. A crop was safe for the Indians, who used only the ears, before the farmers who place great value upon the entire plant would consider it time to harvest the stalks, because they can transmute the stalks into profit by feeding them to growing live-stock.

Jenks says, "The Ojibways at La Pointe, in Chiquamegan Bay, Lake Superior, which is four miles south of the parallel

47° raised corn and pumpkins."[25] John Tanner refers to the Indians planting corn more than a hundred years ago upon the Red River of the North and upon the Assiniboin which is much farther north than this.[26] Any time after the "green" or "milk" stage, even if frosted, corn had food value; especially is this true of the wrinkled or "sweet" varieties. Green corn was dried and if the ears were advanced to the stage of "glazing," by careful curing, could be preserved upon the cob.

It is a fact that by selection of early maturing seed or of seed that made yields under adverse circumstances, the Indians had accomplished much more in adapting corn to soil and climate than the white farmers did before the time of agricultural experiment stations.

The yields of corn can only be guessed at. One familiar with corn growing, barring extremely wet seasons, severe droughts, hail-storms and other unusual behavior upon the part of Providence, by observing the soil, can make fairly close estimate upon how many bushels per acre may be expected. Cultivation after planting has very much more to do with growing corn than with any other cereal. The old cone-shaped hills indicate that much attention was given to hoeing. Early observers state that they saw bounteous growths; others that the promise in mid-season of much of a crop was small. Mr. George Will, an ethnologist of high standing and a specialist in corn growing, says that, among the Sioux and the Cheyennes, twenty bushels per acre was a fair yield.[27]

Mr. M. L. Brown[28] writes that the average yield of corn in Iowa with good white man's tillage has varied from 14.8 to 45.8 bushels per acre, taking the state together, the wide difference being due to weather conditions. For Michigan, in 1924, the average yield per acre was 26 bushels. I should say, being somewhat familiar with the soils of Michigan and corn-raising,

[25] *Report of the American Bureau of Ethnology*, 19, Part II, 1040.

[26] *A Narrative of the Captivity and Adventure of John Tanner during Thirty Years Residence among the Indians in the Interior of North America*, 1830, p. 180.

[27] *Corn among the Indians of Upper Missouri*, p. 142.

[28] *Corn Growing, Judging, Breeding*, p. 74.

that for the Indians, after the predatory animals and birds had taken their toll, fifteen bushels of ears to the acre was a "paying" crop.

When I commenced this dissertation, I had in mind only a description of those old planting grounds and storage pits of Michigan with which I am familiar. But the subject has become so absorbing to me that I venture to submit the following comments and compilations upon the corn-plant and its development. I should also like to mention and describe briefly the religious and social ceremonies and celebrations that different tribes had and held at planting and harvesting, the different ways of preparing corn for the "table," and the long list of names given to the numerous preparations, which is also an absorbing subject and would show that many words have been taken over from the Indians' language into ours. To do all that comes to mind would consume a volume and after all would be largely a repetition of what is already known.

Corn is usually referred to as maize or *Zea mays,* especially by those who write technical treatises. Abroad, the word corn is used to designate all cereals, as wheat, rye, barley, rice, millet and buckwheat, and causes confusion when applied specifically. In an account written more than seventy years ago is the following: "Some time since in one of the counties of Pennsylvania a man, having been indicted for stealing so many bushels of corn, exception was taken by his counsel that this was not a perfect description of Indian corn. The exception was, however, overruled by court, who thus decided that in American jurisprudence 'corn' was the established name of Indian corn." [29]

Corn is one of the "most intriguing mysteries" of the new world. For perhaps five thousand years it has been a differentiated grain very like what it is today.[30] It has been developed by Indians from some very dissimilar grass of Middle America, which had no value as human food. In a tangled mass of botanical evidence, the probabilities are that the parent plant is what is called *teocentili,*[31] a Mexican grass grown in some parts for its

[29] *United States Magazine,* Vol. II, June, 1855.
[30] Kempton, *Maize and Man,* p. 35.
[31] Kroeber, *Anthropology,* p. 353.

fodder, which is very much more dissimilar in its fruit to corn than rose hips are to "northern spies." Although the intermediate forms are extinct, corn, as developed under cultivation, has been identified in a grass that presents but the remotest resemblance to it. One need not be surprised at this because there are many other examples of equally wide differences between domesticated plants and their wild originals. "Who would have thought that the peach and the nectarine came from one stock? Who would have thought that the cabbage, cauliflower, broccoli, and kohl-rabi are derived from one species: and rape, colza, turnip and probably ruta-baga from another species?" [32]

The preparation of foods from poisonous roots and the making of edible meals and food starches from acrid bulbs by boiling and treating them with alkalis are complexes involving the knowledge of their dangerous properties in the raw state and much technical manipulation. Cassava, as it comes from the ground, "carries a deadly charge of prussic acid" and requires special preparation to make it palatable, but, when prepared, was a staple food of the Indians of a large part of South America and is used in almost every household now, under the trade name of tapioca.[33]

So far as evidence goes, all the corn-growing tribes used about the same methods of cultivation. A description of the "technic" in one locality practically describes them all, although on the New England coast and probably in some other places fertilizers were used and, in the southwest, irrigation. The early settlers of eastern Massachusetts speak of the great quantities of alewives in the rivers, which the Indians could easily take in abundance. One or two alewives were put into a hill. The whites imitated the Indians in this particular, and it is possible that the use of "animal fertilizer" was originated by the aborigines.[34]

Captain John Smith's description (1606) of corn cultivation

[32] Asa Gray, *Darwiniana*, 1876, p. 111.

[33] C. F. Cook, *Food Plants of Ancient America;* and *Smithsonian Report for Year Ending June, 1903.*

[34] Wilder, *American Anthropologist*, July–Sept.; also, G. E. Ellis, *The Redman and the White Man in North America*, p. 175.

in Virginia summarized, is: Ground is prepared by girdling the trees to kill them. Fire is applied at the roots to prevent their sprouting. The next year, "With a crooked piece of wood they beat up the weeds by the roots and in that mould they plant their corn — they make a hole in the ground with a sticke and into it they put four graines of wheate [meaning maize] and two of beans." The holes are about four feet apart and when the corn is "grown middle high" they hill it up like a "hop-yard." "What they plant in April they reap in August; for May in September; for June in October." I should say his description of the preparation of the ground by killing the trees, cultivating, and hilling would apply to the old plantings of Alcona County, Michigan, as well as to Virginia.

Professor L. A. Chase of Marquette gives an illustration of Indian corn-lots in Wisconsin in which the rows are in ridges instead of conical hills.[35]

The following is from Darwin:[36] "The varieties also differ in precocity, and have different powers of resisting dryness and the action of violent wind. * * * The tall kinds grown in southern latitudes, and therefore exposed to great heat, require from six to seven months to ripen their seed; whereas the dwarf kinds, grown in northern and colder climates require only from three to four months. * * * . . . in proceeding from south to north, the plants steadily diminish in bulk."[37] Seeds brought from latitude 37° in Virginia and sown in latitude 43°–44° in New England produce plants that will not ripen their seed, or will ripen them with the utmost difficulty. Seed taken from New England to latitude 45°–47° in Canada behaved the same way. After some years of painstaking culture, southern kinds can be readily ripened in northern localities. This is somewhat analogous to the conversion of summer or spring wheat into winter wheat. The differences in the growth of corn are very great. Darwin states

[35] *Michigan Agriculture; Historical Background.*

[36] *The Variation of Animals and Plants under Domestication*, 1: 339–340.

[37] The last statement in the quotation is based upon P. Kalm, *Description of Maize*, 1752. The first three sentences following the quotation are paraphrased from Darwin's digest of Kalm.

the height varies from 15–18 feet to only 16–18 inches, and the size, color and length of cob, the size and shape of the kernel also display as great variation. There are kernels so large that Indians eat them separately like grapes [38] and others small as grains of wheat like pop corn. In shape of kernel there are wrinkled or puckered, dent, beaked, and rounded varieties. The color of the varieties varies from white, through yellow, red, purple, blue to almost black. The arrangement upon the cob if in rows is from eight to twenty, and with some kinds the kernels are not rowed at all.[39] In general, it may be said that if we go north or south from a given latitude a season becomes one day later or earlier for each ten miles of travel.[40] Taking this as a kind of rule, one can figure out very accurately the limit of Indian corn culture and draw his own isotherm, bearing in mind that the shortest growing season for any variety must be ninety days without frost.

Upon archaeological evidence it can be proved to a reasonable degree of certainty that corn culture was practiced a very long time by the prehistoric occupants of Michigan. Many beautiful specimens of mortars and pestles, no doubt made for reducing corn kernels to meal, have been collected within the state. Some of these mortars are made of hard glacial boulders, show excellent workmanship both upon the outside and within, weigh as much as sixty pounds, have grinding holes six to ten inches deep and will hold three quarts or more. Stone pestles are much more common than mortars. Some of those "of the roller type" are two feet long, many eighteen inches and over. Generally, these pestles are beautifully wrought out of hard stone.[41] It does not seem that any people would take so much pains to work out milling implements unless they were of very important practical use. A thesis could and should be prepared upon the workmanship, uses and distribution of mortars and pestles in Michigan. Large,

[38] J. H. Kempton, *Maize and Man*, p. 42.

[39] Darwin, *The Variation of Animals and Plants under Domestication*, 1:338–340; also *Maize and Man*.

[40] T. F. Hunt, *Cereals in America*, p. 203.

[41] See illustrations in *Primitive Man in Michigan*, by W. B. Hinsdale.

deep, wooden mortars were made by gouging out one end of a solid log, usually birch or soft maple, to the depth of from ten to fifteen inches. Each mortar had a double-ended pestle usually made of ironwood about four feet long. Such "Indian mills" are in occasional use today among the Chippewas and Ottawas. They appear to be reproductions, in wood, of the old stone mortars, and have about the same cubical capacity.

The late Professor W. J. Beal, having an intimate knowledge of Indian ways, referring to Lenawee and Hillsdale counties says: "Indians hilled up corn and planted each succeeding crop in the same old hills. They made primitive grist-mills in this way: A long pole or sapling was pinned to a tree, like a well-sweep; a small pole was suspended from the elevated end of the sweep, the lower part of which was pestle-shaped; the top of a stump was hollowed out to hold the corn. The sweep was then worked up and down by one of the squaws, while another steadied and directed the pestle, which smashed the corn as it came down." [42]

The Indians of the Michigan country are classified culturally as having been in the hunter stage but, in fact, they were equally dependent upon agriculture. The men did the hunting; the women cultivated the fields. The entire technique of the Indian woman's corn culture has been taken over by the white planters; the method of planting in hills or drills, hoeing or weeding, husking, storing in cribs, milling and the conversion of the shelled grain into mush, hominy, cakes, "green corn" and ingredients of breads and broths.

University of Michigan

[42] *Pioneer Life in Southern Michigan in the Thirties, Michigan Pioneer Collections*, 32: 237.

THE FLORA OF A RECENTLY EXPOSED SHOAL, WHITNEY BAY, DRUMMOND ISLAND, MICHIGAN

CECIL BILLINGTON

ON SEVERAL occasions it has been my good fortune to be invited to spend my vacation period on Arnold Island, in Whitney Bay, Drummond Island, in the upper end of Lake Huron. Arnold Island is owned by Dr. Chas. H. Baker, of Bay City, and E. O. Marsh, of Jackson, Michigan, and is used by them and their families as a refuge from perennial attacks of hay fever.

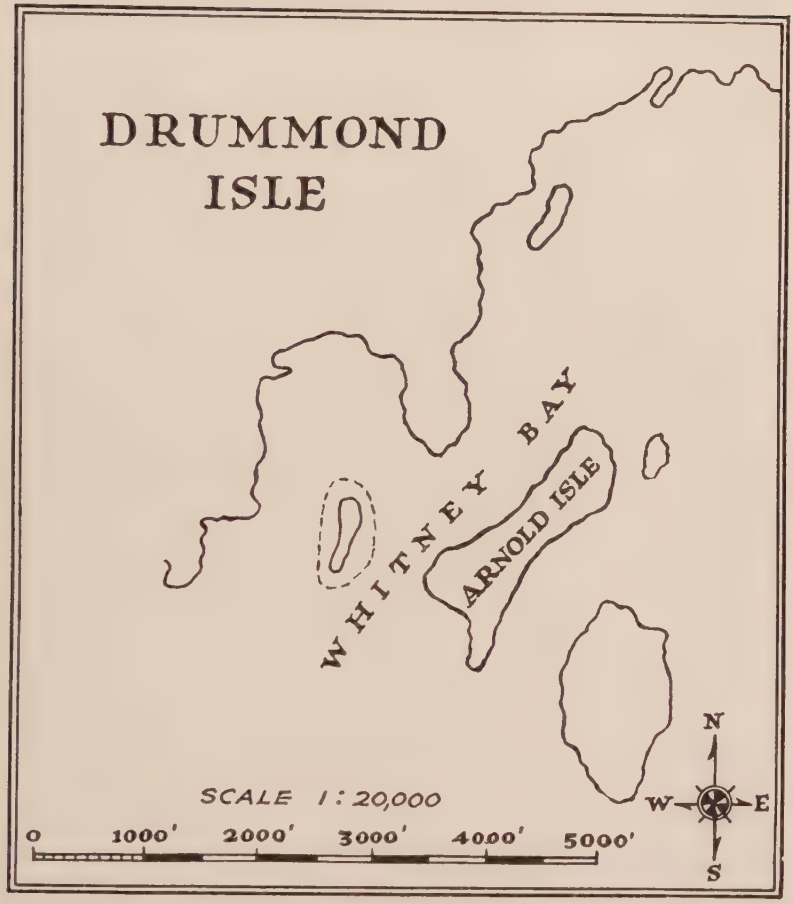
My last trip to the island was in the fall of 1925 from about August 20 to September 2. At this time it was noted that the low water prevalent over the Great Lakes had uncovered a strip of shoal which, so far as was known, had not before been exposed, certainly not in recent years. Curiosity as to the character of the uncovered shoal led to a visit. That it had been out of the water only a short time was evident as there was as yet no accumulation of fertile soil. The exposed shoal was composed of rocks of varying size, coarse gravel and sand. It was apparent that it had been subjected to very little weathering. The visit revealed that quite an abundant flora had already taken possession, and it was thought that circumstances warranted making a record of it as far as possible.

The accompanying map (Map 1), which was furnished by the United States Lakes Survey, clearly indicates the position of the shoal in the channel about mid-way between Arnold Island and the Drummond mainland. The dotted outer line is the twenty-one-foot depth contour and the smaller solid line the six-foot depth contour, so that the exposed portion is approximately in the center of the area enclosed by these lines. There are a great

many exposed rocks in the channel, particularly close to the shore of both Drummond and Arnold islands, and two or three of the larger rocks of this shoal had doubtless been awash for many centuries. Arnold Island, which is about a half-mile long, is merely a huge rock pile with a thin covering of vegetation and in only a few short spaces of shore-line is there any sandy beach. This newly exposed shoal is apparently the top of a gently sloping hill which lies in the bay. The receding waters had exposed the top of the hill leaving it from eight to ten inches out of the water. At the time of this survey there was exposed an irregular area three or four hundred feet long by possibly a hundred feet at the widest point. It lies approximately 800 feet from the nearest mainland shore upon which there is growing any kind of vegetation. This is toward the west. Toward the east the nearest point is about 900 feet, to the north about 1000 feet, while to the south there are only the waters of Lake Huron. The photographs of the shoal (Pl. I, Figs. 1 and 2) taken at the time the survey was made give a very clear idea of its character.

Upon consultation of the United States Lakes Survey records Mr. Sherman Moore, one of the engineers in charge of Lake Survey work, found that the shoal was first exposed during the extremely low stage of water which occurred the last of November and the first of December, 1924. At this season in the latitude of Whitney Bay winter has set in and there are ice and snow so that, while the water may have uncovered the shoal, it was not exposed for the accumulation of seeds until the ice went out in the spring of 1925, or about the middle of April. My inspection was made about the last of August and in the interim the vegetation which I found growing had established itself.

The following is a list of the plants found so far as they can be identified. Owing to the fact that several of the plants were only seedlings, it has not been possible to get the specific name and as regards grass, not even the generic name. The nomenclature used is that of Gray's *New Manual of Botany* (seventh edition).



Map 1. Sketch map of the western portion of Whitney Bay, Drummond Island, Michigan, showing the location of the newly exposed shoal in the channel about mid-way between the Drummond mainland and Arnold Island. The dotted line is the twenty-one-foot depth contour and the inner solid line the six-foot depth contour. The exposed portion is approximately in the center of the area enclosed by these lines.

PINACEAE (Pine Family)

Thuja occidentalis L. (Arbor Vitae, White Cedar). — Numerous very small seedlings.

GRAMINEAE (Grass Family)

Avena fatua L. (Oat). — One tuft of several branches with fully developed grain.

Agropyron tenerum Vasey. — Several tufts with fully developed grain.

Gramineae. — A large number of seedlings apparently all of one genus, but not large enough to determine.

CYPERACEAE (Sedge Family)

Cyperus sp. — Numerous small seedlings.

Scirpus sp. — A few small round rushes, probably *S. validus* Vahl., but not well enough developed to determine definitely.

SALICACEAE (Willow Family)

Salix sp. — Several very small seedlings, probably of the sand-bar willow.

BETULACEAE (Birch Family)

Betula sp. — Very numerous, probably numbering a hundred or more small seedlings.

POLYGONACEAE (Buckwheat Family)

Polygonum ramosissimum Michx. — One large, branching plant in full fruit.

Polygonum lapathifolium L. — Several plants in flower and fruit.

Polygonum lapathifolium L. var. nodosum Weinmann. — Several plants in flower and fruit.

Polygonum acre HBK. var. leptostachyum Meisn. — One plant in flower and fruit.

Polygonum Convolvulus L. (Black Bindweed). — Several well-developed plants in flower and fruit.

CHENOPODIACEAE (Goosefoot Family)

Salsola Kali L. var. tenuifolia G.F.W. Mey. (Russian Thistle). — One small plant.

RANUNCULACEAE (Crowfoot Family)

Ranunculus sceleratus L. (Cursed Crowfoot). — One small plant in fruit.

CRUCIFERAE (Mustard Family)

Brassica nigra (L.) Koch. (Black Mustard). — One small plant in flower and fruit.

ROSACEAE (Rose Family)

Potentilla sp. — Several small seedlings.

LEGUMINOSAE (Pulse Family)

Trifolium sp. (Clover). — One small seedling.

BALSAMINACEAE (Touch-me-not Family)

Impatiens biflora Walt. (Jewelweed). — Several large, bushy plants in full flower and fruit. This had reached the greatest development of any of the plants on the shoal.

ONAGRACEAE (Evening Primrose Family)

Epilobium angustifolium L. (Fireweed). — Numerous plants in all stages of flower and fruit.

Epilobium adenocaulon Haussk. — Several plants in flower and fruit.

Oenothera sp. — Numerous small seedlings.

UMBELLIFERAE (Parsley Family)

Pastinaca sativa L. (Parsnip). — One seedling.

ASCLEPIADACEAE (Milkweed Family)

Asclepias sp. — One seedling.

LABIATAE (Mint Family)

Lycopus americanus Muhl. (Water Horehound). — Very numerous and some plants in fruits.

SCROPHULARIACEAE (Figwort Family)

Melampyrum lineare Lam. (Cow Wheat). — One small plant in bud.

COMPOSITAE (Composite Family)

Aster macrophyllus L. — Several seedlings.

Erigeron canadensis L. (Horse-weed). — Several depauperate plants in fruit.

Anaphalis margaritaceae (L.) B. and H. (Pearly Everlasting). — Numerous plants, some in blossom and fruit.

Rudbeckia hirta L. (Black-eyed Susan). — Several seedlings.

Erechtites hieracifolia (L.) Raf. — One small plant with three blossom heads.

Cirsium sp. — Several small rosettes of leaves.

Cirsium arvense (L.) Scop. (Canada Thistle). — Numerous small plants.

Taraxacum officinale Weber. (Common Dandelion). — Several plants.

Sonchus asper (L.) Hill. (Spiny-leaved Sow Thistle). — Several fully developed plants with numerous flowerheads.

The list comprises eighteen families, twenty-nine genera, thirty-five species and varieties. It naturally becomes at once a matter of speculation as to how such a comparatively abundant flora should so quickly take possession of this rocky shoal nearly a thousand feet from the nearest vegetation. Generally speaking there are but two methods by which the seeds could have been

conveyed to the shoal, by wind and by water. While birds may have been a factor, the barren character of the shoal did not make it attractive, except possibly to a few water-fowl, and would doubtless very materially reduce the chances of this method of distribution.

While there is no published flora available with which to check, the plants found on the shoal would doubtless also be found on the mainland or on the adjacent islands. If this should not prove to be so, it is not impossible that some seeds from distant localities may have found their way to the shoal through the medium of the Great Lakes shipping, the main channel, through which boats from all parts of the lakes are continually passing, being only about a mile distant. It is, perhaps, not drawing too hard upon the imagination to picture one seed of *Avena fatua* L., for instance, which is not reported from Michigan in Beal's *Flora* of the state, but is common westward, in some way getting on a boat at Duluth or some other western point and being swept or blown from the boat into the water in the vicinity of Whitney Bay, eventually to land upon our tiny shoal, there to sprout and grow.

Of the thirty-five species and varieties found on the shoal, twelve have wind-borne seeds. This is almost exactly one third of the total number of species. Of these, six had produced plants which were in flower and six were only seedlings. It is probable that none of the plants which were in flower were grown from seeds produced during the same season. The Salix and Taraxacum seedlings may have been, on account of the early flowering of the species. It is likely, however, that all the plants on the shoal whether wind- or water-borne were grown from seeds which were produced during the previous season. The fact that the shoal was not uncovered until after the close of the fruiting season may seem an obstacle to this supposition, particularly for the wind-borne seeds. But it is supposable that seeds blown from the plants during the winter might lodge on the ice where they would find ready transportation to the shoal during the spring break-up, the character of the bay being such that rafts of ice would no doubt be driven from point to point by the

wind and waves. Or they might float to the shoal after being liberated by the melting of the ice.

Twenty-three of the species on the shoal came from seeds which had some other means of distribution than the wind, and the most probable theory is that they reached their destination by means of the water. Of these, twelve, or slightly more than half, were in flower and fruit, and eleven had not yet reached that stage. As in the case of the wind-borne seeds, it is not likely that any of the plants came from seeds produced the same season. It is probable that the parent plants were growing in a situation where their seeds were dropped into the water or on the ice, or that the seeds were brought to the vicinity by the boats or other outside agency and were floated to the shoal by the action of the wind and waves.

Of the thirty-five species on the shoal thirty-two are herbaceous and three woody plants. It will be observed that of the herbaceous plants eighteen, or over fifty per cent, were in flower and fruit. Many of the individuals were stunted and with only a few flowers, owing to the lack of fertile soil, but that so many plants should be found at all in such a situation and especially that they should produce fruit, seems remarkable. It illustrates the rapidity with which vegetation will take possession of an area even under very adverse conditions.

Mr. Sherman Moore, of the United States Lakes Survey, is of the opinion that such a shoal, when once exposed, will never again be flooded unless resubmergence occurs very soon. The action of the waves piles the gravel and stones higher, washing them up from below; soil is accumulated through the process of weathering and the addition of débris; vegetation establishes itself, and in a comparatively short time another island is formed.

Detroit, Michigan

EXPLANATION OF PLATE I

FIG. 1. A view toward the northerly end of the newly exposed shoal in Whitney Bay, Drummond Island, Michigan

FIG. 2. A view of the same shoal looking toward the south. This shows the large rocks which were awash before the low water exposed the rest of the shoal

Both photographs were taken by Mr. Lee A. White on the day the survey of the flora was made the last of August, 1925.

PLATE I

FIG. 1

FIG. 2

SAPROPHYTIC FUNGI ASSOCIATED WITH THE HONEY BEE *

CARLTON E. BURNSIDE

IN VIEW of the fact that fungi occur commonly on and inside bees and on brood-combs, a thorough knowledge of these forms has interest to both the mycologist and the bee-keeper. It may be expected that a thorough survey and study of this relation will yield a large number of species of fungi hitherto unreported as having any connection with bees, as well as new species, for conditions prevailing within beehives are unusual. Much damage is done annually by fungi within the beehive through the destruction of pollen, brood-combs and bees and brood. It is, therefore, an advantage to the bee-keeper to understand something of the nature of these fungi. Such an understanding can come only from the records obtained by careful investigations.

This paper is intended to record results obtained during an extensive survey of relation with bees, of the saprophytic life, of some fungi that occur within the beehive. The pathogenic relation is not a part of this paper and will be dealt with elsewhere.

Chief among the factors accountable for the rich fungus flora of the bee and the beehive is the constant and widespread foraging of the worker bees through the warmer part of a season. This results in a constant carriage of spores into the hive and explains the presence of the variety of forms which one constantly finds within the alimentary canal of the bee. The larger part of the forms collected by the bees are probably unable to become established within either the bee or the beehive. A

* Paper from the Department of Botany of the University of Michigan, No. 263.

number of other forms appear to find lodgment on and in the bee, particularly after death, and the brood-combs offer favorable conditions for their development and spread. A few forms with parasitic tendencies develop within the living bees or their brood. Most of the forms found on dead bees in late winter or early spring are saprophytes that develop after the death of the bees. The spores of some fungi are killed after a short time in the alimentary canal of the bee. Others are able to resist for weeks the action of the digestive fluids of the bee and although unable to germinate during the life of the bee, they do so soon after death, mummifying all the softer tissues inside the exoskeleton. Still other forms do not germinate within the bee either before or after death, but remain viable and germinate when placed on plates of nutrient agar. Dead bees that collect on the bottom board may also be attacked by the mass of mycelium that grows over and among them, gaining entrance to the body through the body openings or through the softer parts of the exoskeleton.

Development of fungi upon brood-combs, pollen and honey is dependent upon a number of easily understood factors. Sufficient food in the form of honey, pollen, and other things, must be present upon the combs in order to provide nourishment for the continued spread of the mycelium. This condition usually exists upon combs that have been used for brood-rearing and for storage of honey and pollen, even though the surface of such combs may appear entirely clean. Freshly drawn combs in which brood has not been reared and honey and pollen have not been stored are not overgrown by fungi. Other necessary conditions are the presence of sufficient moisture and temperatures lying between the growth limits of the forms present. A high humidity, near or at the saturation point, without condensed water, provides sufficient moisture for some of the forms inhabiting the beehive.

Through proper regulation of humidity within the hive by the bees, they are able to protect themselves and their stores from the attacks of fungi. In regions of low humidity and in late spring, summer and autumn, the humidity within the hive

is most easily kept at a low point, preventing most of the fungus growth. A dry condition is also maintained through the winter in strong colonies with proper food and insulation if provisions are made for the escape of water vapor. In weak colonies the hives are less completely ventilated and the condensation of metabolic water may result in the wetting of the combs and bottom board, or even of the bees. The presence of sugars of low concentration, such as unripened honey, results in the formation of large amounts of water vapor. This is due to the oxidation of such sugars during their digestion by the bees. On the contrary well-ripened honey or sugars of as high a concentration as can be maintained without crystallization, produce a minimum amount of water. After the death of the colony (during wintering) the air in the hive is stagnant. Under such conditions water vapor rises from the decaying bees on the bottom board, moistening the combs above.

In looking back to see what data have already been gathered in this field, one notes that the fungi which occur within the alimentary canal of the bee and within the beehive have already been given some attention, but by few mycologists. Several species have been reported from time to time (mostly in Europe), as occurring on bees and combs, some of which have been suspected or shown to be the cause of disease among bees. Many of these reports are of a non-scientific nature and in some the identity of the fungus is uncertain or its existence doubtful. The most recent and only extensive treatment of purely saprophytic fungi occurring within the beehive is found in the work of Miss Betts (1). She reviews what has been done on beehive fungi up to 1912 and describes forms that she isolated from combs upon which colonies had died. A new fungus species, *Pericystis alvei* Betts, is described by her. The bibliography in Miss Betts' paper of the early literature on beehive fungi is fairly complete up to 1912; consequently, it will not be reviewed again here. Since the work of Betts a number of reports dealing with fungus parasites of the honey bee have appeared, as well as one extensive paper by Fielitz (2) which deals with the saprophytic and also the parasitic relations of some fungi

that occur regularly on dead bees. Fielitz mentions three fungi, *Trichoderma lignorum*, *Penicillium glaucum* and *Mucor mucedo*, which are associated with mummification of adult bees or their brood. As a result of his series of experiments he concludes that *Penicillium glaucum* is purely saprophytic while *Trichoderma lignorum* and *Mucor mucedo* may under certain conditions attack living bees or their brood. Notes are given in this paper on the morphological and cultural characteristics and physiological reactions of the strains studied.

The fungi here discussed were collected during the past three years from bees and beehives at Ann Arbor, Michigan, and at the apiary of the Department of Agriculture, Washington, D. C., as well as from bees from various parts of the United States, sent to the writer through the Bee-Culture Laboratory of the Department of Agriculture.

The groups of fungi discussed here are considered in the order of frequency with which they occur within the beehive on combs or stores, as indicated by the frequency with which they have been isolated during this investigation. Those discussed under group headings have been isolated constantly and appear in great numbers within the hive, especially during the spring or late winter. Those grouped under the heading "Miscellaneous Genera" have been observed to occur less frequently. Some of these forms have been isolated from bees or beehives but a few times, while others have been identified only once on bees and may have been of accidental occurrence. Still other forms different from those discussed here have been isolated although sufficient study has not been given these to determine their identity. This is especially true of the forms in the genus Penicillium.

In her paper on beehive fungi, Betts (1) discusses only two species of Penicillium, *P. crustaceum* Linn. and a second form which she believes is the species studied by Brefeld and referred by him to *P. glaucum* (Lafar, 18, p. 333). Other fungi described by Betts as occurring within the beehive are: *Eremascus fertilis* Stoppel, *Gymnoascus setosus* Eidam, *Gymnoascus ruber* Van Tieghem, *Aspergillus glaucus* Link, *Aspergillus nidulans* Eidam,

Citromyces glaber Wehmer, *Citromyces subtilis* Bainer and Sartory, *Sordaria fimicola* Rob., *Mucor erectus* Bainer, *Oospora favorum* Berkeley and Broome, and *Pericystis alvei* Betts.

The writer is convinced that the number of forms of Penicillium as well as of other fungi that occur within the beehive is far greater than even the list given in this paper.

PENICILLIA [1]

This group of fungi, ubiquitous in their habits, is the most extensively spreading and the most common group within the beehive, where it is found on the combs and the dead bees. While examining colonies in early spring, the writer has frequently found entire combs and at times after the death of the bees all the combs of a hive entirely overgrown with these organisms. This condition is aided by the fact that many of the species of Penicillium common in the beehive appear to grow well under wide ranges of moisture and temperature; especially is this true of all of the combs not actually occupied by bees. Neither stored pollen nor honey is extensively attacked, but the almost imperceptibly small amounts of honey and pollen present on brood-combs provide food for their continuous spread within the hive. Actual parasitism of bees has never been established for any of the species of Penicillium, although the damage done by their growth on brood-combs appears to be considerable. Badly infected combs are not only unsightly, but are not readily accepted by the bees. With the expansion of the colony, combs overgrown with Penicillium are cleaned and used for brood-rearing and storage. A few species of Penicillium produce strong odors. At least one of these occurs extensively within the hive as is readily determined by examining hives of badly infected combs. Bees are unusually sensitive to strong odors, the presence of which within the hive seems to have an injurious effect upon the morale of the colony. Under such conditions, weak

[1] Complete descriptions of the morphological and physiological characters of the species of Penicillium discussed in this paper are given in the works of Thom (6), in the work of Westling (8), and in Rabenhorst's *Cryptogamic Flora* (4).

colonies will sometimes desert the brood nest after it has been started and move away from the encroaching fungi. Weak colonies in hives with badly infected combs have been observed to establish their brood nests very near the entrance of the hive even during the cold days of early spring in order to escape, so far as possible, the strong odors of Penicillium. After thorough drying and the disappearance of odors, these combs appear to be less objectionable, and as long as they are readily accepted may be used without damage to the bees except for the labor required in cleaning them.

Species of Penicillium are likewise commonly found on dead bees on the bottom board of the hive. Microscopical examination of tissue cultures of such bees proves the presence of Penicillium more often than of all other forms of filamentous fungi. Cultures from the alimentary canal of dead or living bees nearly always yield one or more species of Penicillium.

Penicillium corylophilum Dierckx. — Among the most common species of Penicillium that attack brood-comb and bees after death is *Penicillium corylophilum*. This species has been observed covering entire combs and grows upon anything about the hive over which even minute quantities of food (honey and pollen) are spread. It enters the cells of brood-combs and spreads over the sides and bottom of the cells, but the strongest growth is usually at the mouth of the cells on the lower part of the comb. It gives to brood-combs a mottled appearance of green, yellow and brown. This species also grows saprophytically upon bees and it has often been isolated from tissue culture of bees collected from the bottom board. It appears to require only small amounts of moisture for growth; consequently it develops on combs under conditions too dry for growth of other fungi.

Penicillium cyclopium Westling. — This species of Penicillium has been constantly isolated from bees and from brood-combs from various sections of the United States. It seems to occur less commonly on brood-combs than does *Penicillium corylophilum*, perhaps as a result of its greater moisture requirements. It gives to the combs a green color with occasional faint evidence of gray or yellow. It develops well on dead bees that collect on

the bottom board, mummifying the softer tissue and forming considerable white mycelium on the surface, which may later produce conidiophores and green conidia.

Penicillium palitans Westling. — *Penicillium palitans* occurs commonly on both bees and brood-combs. It gives a dull green

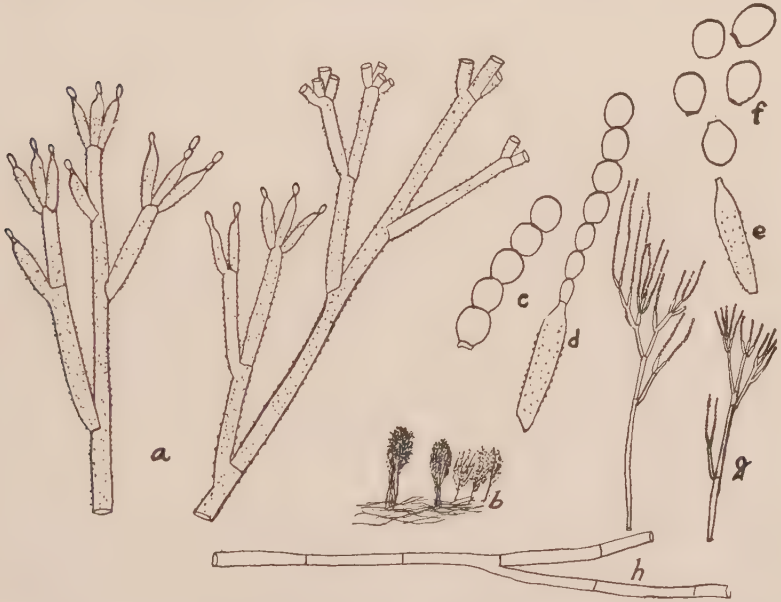


FIG. 2. PENICILLIUM GRANULATUM (Bainer), *sensu* Thom. *a*, conidiophores showing granulated echinulate cell walls; *b*, showing coremia formation and separate conidiophores; *c*, chain of conidia; *d*, conidiiferous cell with conidia; *e*, conidiiferous cell; *f*, conidia; *g*, conidiophores with chains of conidia

color to combs through the early production of conidia. Its appearance on bees is similar to that on combs. The formation of spores occurs earlier on bees than with *Penicillium cyclopium*, hence the white appearance resulting from sterile mycelium is usually absent.

Penicillium expansum Link, *sensu* Thom. — This species has been isolated regularly from both bees and combs producing

gray-green colors upon their surfaces. Coremia, which are readily produced by this organism, occur commonly on bees, but are less noticeable on combs. This seems to be the species described by Betts (1) under *Penicillium crustaceum* L.

Penicillium chrysogenium Thom. — This species has been observed to occur abundantly on brood-combs and bees in Michigan. It spreads over considerable portions of the combs and develops in and on bees. Isolations of this organism have been made from bees and combs after the death of the colony.

Penicillium granulatum Bainer, *sensu* Thom (see Text Fig. 2). — On one occasion this species was isolated from a brood-comb on which it had spread over the surface in an almost pure culture. It has not been observed on bees and is evidently not of common occurrence in the hive.

Penicillium commune Thom. — The strong moldy odors produced within beehives when plentiful moisture is present on the combs appears to be due, at least in part, to *Penicillium commune* and closely related forms. These odors remain within the hive for weeks during the spring in colonies too weak properly to ventilate the hive or make a thorough job of house-cleaning. The organism has been isolated from both combs and bees. The odor appears in cultures grown on Leonian's agar and peptone agar as well as on potato cultures and, according to Thom, on a number of other media. When combs are ventilated and dried the strong odors disappear.

Penicillium brevicaule Saccardo, *sensu* Thom (see Text Fig. 3). — This curious species of Penicillium has been isolated repeatedly from bees, although it has never been observed on brood-combs. It forms a yellowish to brown coating, powdery in appearance when dried on the bodies of dead bees. It develops slowly on bees and does not appear until from five to ten days after death.

Penicillium brevicaule Sacc. var. *album* Thom. — The morphology of this species on bees appears to be identical with that of *Penicillium brevicaule*, except that the spores remain white; consequently a brown coating does not develop over the bees as in the typical species.

Penicillium glauco-ferrugineum Sopp. — This species was isolated only once, on which occasion it appeared on the abdomen of a dead bee which was sent to the writer for examination from the Bee-Culture Laboratory of the United States Department of Agriculture. It certainly is not common in the beehive or on bees.

This list of species of Penicillium occurring within the bee-

FIG. 3. PENICILLIUM BREVICAULE (Saccardo), *sensu* Thom. *a*, conidiophores with conidial chains, older spores echinulate, young spores smooth; *b*, complex conidiophore; *c*, simple conidiophores; *d*, portion of mycelium; *e*, trailing hyphae bearing conidiophores; *f*, mature conidia after becoming echinulate

hive is not intended to be an exhaustive one. Forms distinctly different in morphological or physiological characters from those discussed here have been isolated from combs and bees from time to time. These have not been identified. Extended study of the species of Penicillium attacking brood-combs or dead bees will undoubtedly yield a list of considerable length.

ASPERGILLI [2]

The Aspergilli occur far less abundantly in the hive and on dead bees than does the group of fungi discussed above. Several species of Aspergilli are, however, pathogenic on living bees and other insects, as well as on mammals and birds. These pathogenic relations are here excluded since they will be treated in another paper. They spread slowly over the combs under conditions usually prevailing within the hive and are frequently crowded out by the more rapid growing and hardy species of Penicillium. The small amounts of honey and pollen present on the brood-combs appear to be insufficient to support rapid development of these organisms. Colonies usually remain confined to a few cells or at most to areas a few inches across. Wet extracting combs afford a better substratum for Aspergilli than do brood-combs. These combs if stored in damp places such as cellars are attacked, for the most part, by the yellow-green spored forms. Combs with more than very small amounts of these organisms should not be given to the bees. Pollen is only occasionally attacked but capped honey never. Strong odors repulsive to bees are not produced by any of the species common in the hive, consequently the morale of the colony is not disturbed. The actual damage done to combs is negligible except in extracting combs as described above. A few species of Aspergilli occur commonly on dead bees and less frequently on their brood during spring, summer and autumn.

Aspergillus flavus-oryzae. — Under this name are placed a number of races or strains of the yellow-green spored Aspergilli, viz., *Aspergillus flavus* Link (*sensu* Thom) and *Aspergillus oryzae* (Ahlburg) Cohn., as well as other related forms; all these occur commonly on bees, brood-combs and frames. During this investigation *A. flavus* has been repeatedly isolated from both dead and living bees and brood, and from brood-combs and frames. This species occurs on bees throughout the active season but rarely on combs occupied by bees. After the removal of

[2] Complete technical descriptions of all the species of Aspergilli discussed in this paper are available (7), consequently they will not be included here.

brood-combs from bees, small tufts may develop upon their surface. The forms designated as *Aspergillus oryzae* occur less frequently, but have often been isolated from dead bees and brood.

Aspergillus fumigatus Fresenius. — Occurs but rarely on brood-combs, but has frequently been found on dead bees. It does little damage to combs or stores and under conditions favorable for its development it is overrun by other fungi.

Aspergillus nidulans (Eidam) Winter. — Resembles *Aspergillus fumigatus* in its manner of growth on bees and combs. It

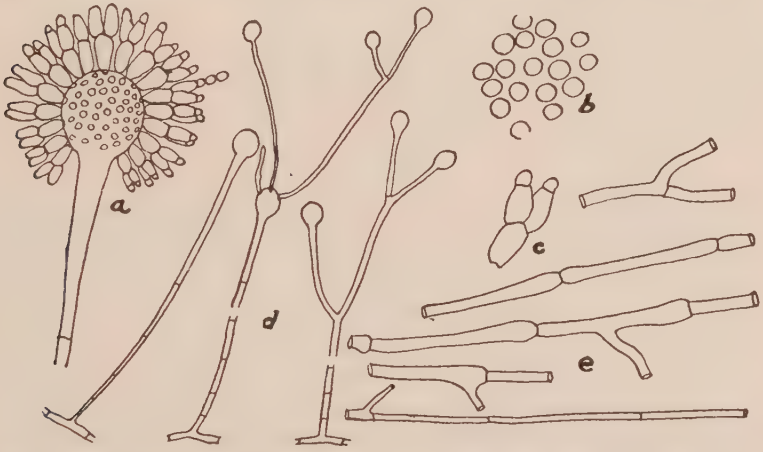


FIG. 4. ASPERGILLUS CANDIDUS Link. *a*, diagram of head; *b*, conidiospores; *c*, sterigmata of first and second series; *d*, types of conidiophores; *e*, mycelium

has been isolated from bees, brood and combs although less frequently than *Aspergillus fumigatus*. It does not injure combs, pollen or honey.

Aspergillus glaucus. — This also is a group name, used in Dr. Thom's sense. Some of the forms of *Aspergillus glaucus* continue to grow under conditions too dry for other species of Aspergilli, consequently they appear on combs under fairly dry conditions and on brood and bees. They grow slowly and do not damage the combs or stores.

The *Aspergillus ochraceus* group, *sensu* Thom. — Strains of *Aspergillus ochraceus* occur rarely on combs and bees; however, one strain has been isolated from adult bees. In two instances it was observed to have spread over brood-combs, but too sparsely to damage them.

The following species of Aspergilli, none of which appear to be of any consequence in beekeeping, are of quite rare occurrence within the beehive, but all of them have been isolated from bees or brood-combs: *Aspergillus niger* Van Tieghem, *Aspergillus versicolor* Vuillemin, *Aspergillus candidus* Link (see Text Fig. 4); *Aspergillus clavatus* Desmiazieres; and *Aspergillus sydowi* (Bainer and Sartory) Thom and Church.

Other forms of Aspergilli than these are probably present at times, but certainly do not occur abundantly within the hive.

THE MUCORS

The mucors do not, as a rule, grow well on brood-combs. Usually the proper conditions do not appear to be present any length of time. Combs and pollen are not damaged by this group of fungi, although small amounts of mycelium species of Mucor have occasionally been observed on brood-combs. Mucors appear regularly on adult bees both on the bottom board of the hive and in shady spots near the hive, especially in the spring. The mycelium permeates the interior tissues and in humid atmospheres spreads over the surface of the bee and sporangia develop abundantly on the surface. Zygospores have frequently been observed on bees in at least one species of Mucor.

Mucor hiemalis Wehmer-Hagem (see Text Fig. 5). — What appears to be a form of this species, at least closely related without very serious discrepancies, was found on bees on several occasions both in the hive and about the apiary. It has been isolated twice from mycelium found vegetating in the ventriculus of living bees.

The attention of the writer was first attracted by zygospores forming on the surface of the exoskeleton of a dead bee through which the mycelium had grown from the inside. Rough isolations from this and other material gave cultures which produced zygo-

spores. Since he suspected that it might be a heterothallic mucor, single-spore cultures were started and eventually the two strains were separated. These reacted negatively to themselves in the usual manner of such sex strains, and produced zygospores when the opposite strains were planted together. It forms zygospores

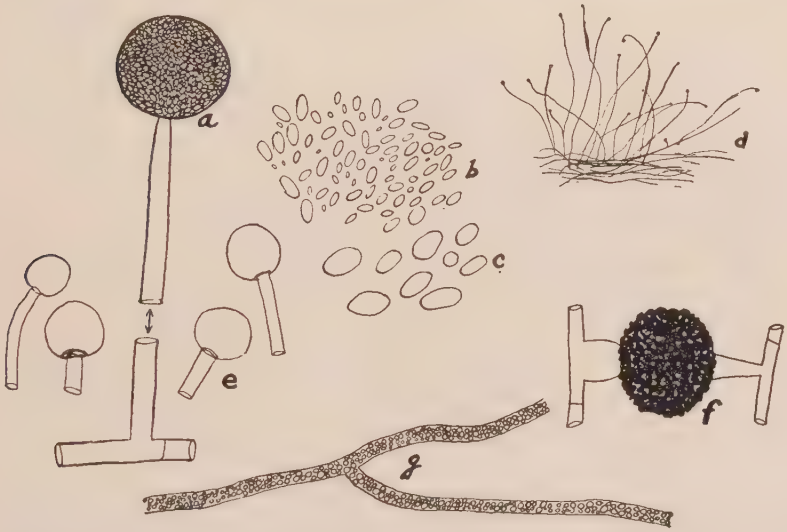


FIG. 5. MUCOR HIEMALIS Wehmer-Hagem. *a*, mature sporangium; *b*, spores with small extremes; *c*, large extremes found among spores; *d*, habit sketch of sporangiophores; *e*, showing shapes with variations of the columella; *f*, mature zygospore; *g*, portion of the mycelium

readily on both Peptone agar and Leonian's agar as well as on bread, at ordinary room temperatures. The usual moisture content used with bread cultures was favorable for both sporangia and zygospores. A description of this form, as it appears on bread, follows:

Turf 1–2 cm. tall, at first white becoming silvery gray to pale gray, at first erect, rather loose, then collapsing. Sporangiophores simple or rarely branched, smooth, without chlamydospores, 15–30 μ in width. Sporangia spherical, smooth, with a hyaline, diffluent membrane, appearing grayish at maturity, 30–80 μ in

diameter. Columella globose or subglobose, 30–55 μ in diameter, smooth, with hyaline content, free, with a persistent basal collar. Spores markedly variable, of two general series of sizes even in the same sporangium, larger size elliptical, about 8–14 (30) × 5–8 (10) μ, rarely subglobose; the smaller size more numerous, more elon-

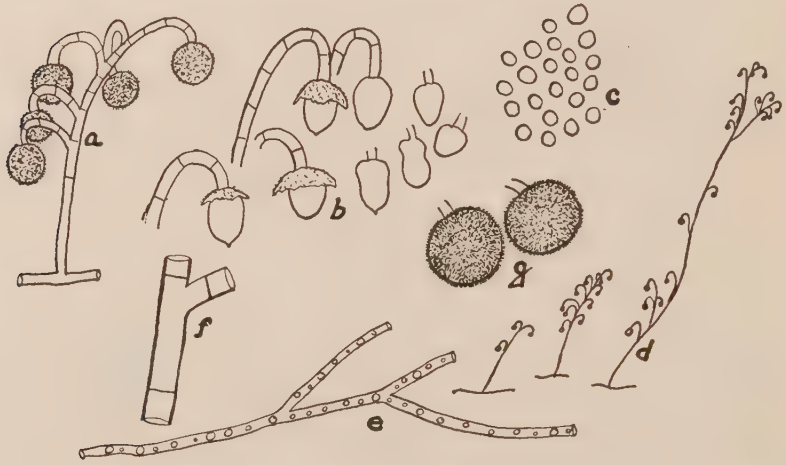


FIG. 6. CIRCINELLA UMBELLATA Van Tieghem and Le Monnier. *a*, sporangiophore and sporangia; *b*, showing variation in shape of the columella; *c*, spores; *d*, types of sporangiophores; *e*, portion of mycelium; *f*, showing origin of branch of sporangiophore; *g*, sporangia

gated and narrower in proportion, 3–7 × 2–4 μ, oblong, smooth, almost hyaline. Chlamydospores become abundant in the substratum, globoid to oval or somewhat barrel-shaped, varying in size and shape, 6–18 μ in diameter. Zygospores globose to somewhat compressed, warty and black at maturity, 50–90 μ in diameter, borne between parallel hyphae, the suspensors short and thick. Heterothallic.

Other isolations of *M. hiemalis*, which were sterile, and whose sporangiospores, although also quite variable, did not reach the large average size associated with this sexual plant, have been made from bees. The form described above agrees in most respects with the account given by Hagem (4). The zygospores may

be more often compressed than globose, and the sporangiospores have a larger range of size. Examination of single sporangia from the individual sex strains showed that the variability was present in each sporangium regardless of the strain, so that this was not a case like that of Mucor III described by Blakeslee (2), in which

FIG. 7. SYNCEPHALASTRUM RACEMOSUM F. Cohn. *a, b,* lateral branches with spherical swollen tips bearing elongated sporangia which break up into spores; *c,* enlarged diagram of mature sporangia and vesicle; *d,* mature sporangium; *e,* spores; *f,* habit sketch three times actual size; *g,* mycelium

the sporangiospores of one strain were regularly larger than in the other strain.

Betts (1) reports *Mucor erectus* Bainier-Fischer, and gives an account of its occurrence and distribution somewhat similar to that of our Mucor. This species is compared by Hagem (*l. c.*) with his *M. hiemalis,* and he comes to the conclusion that it is different. Whether *M. erectus* is heterothallic is unknown. One of the distinguishing features given by Fischer, Betts and others for *M. erectus* is the copious formation of azygospores, a condition which does not hold in *M. hiemalis.*

Other species of Mucor that have been observed and isolated from bees or from brood-combs by the writer are: *Mucor prainii* Chodat and Nechitch, *sensu* Lendner, *Mucor racemosus* Fres., *sensu* Lendner, and *Mucor corymbosus* Harz, *sensu* Lendner.

Rhizopus nigricans Ehrenberg, *sensu* Lendner. — This cosmo-

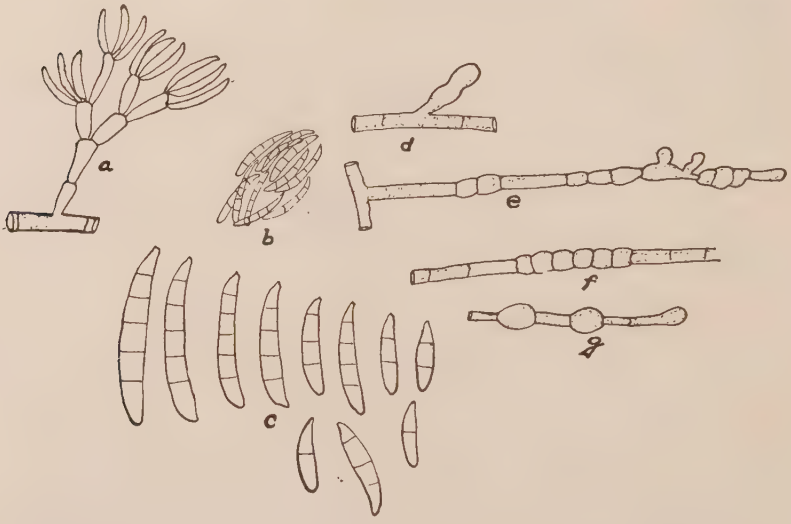


FIG. 8. FUSARIUM NEGUNDO Hubert. *a*, conidiophore with spores still attached; *b*, group of spores showing common arrangement found on agar of culture dish; *c*, spores showing variation in size and shape; *d*, *e*, *f*, *g*, types of chlamydospores

politan species occurs commonly within the alimentary canal of the bee, as can be demonstrated by cultures. It rarely develops on combs, probably on account of insufficient moisture. It has frequently been observed on bees. Both plus and minus strains have been isolated, as was shown by the formation of zygospores when single-spore cultures were placed together on plates of Blakeslee's agar.

Circinella umbellata Van Tieghem, *sensu* Lendner (see Text Fig. 6). — This fungus has been isolated only once from a bee. It appears to be of very rare occurrence in the hive and on bees.

Cunninghamella sp. — One collection of Cunninghamella was made from the ventriculus of a bee where the organism probably existed in the form of spores until isolated and put on agar. It has never been observed on combs. This collection differs from *Cunninghamella elegans* Lendner in size of sporangiophores and spores. The spores measure 6–9 microns on the lateral heads and 9–14 by 6–9 on the terminal head.

Syncephalastrum racemosum F. Cohn (see Text Fig. 7). — This species has been isolated twice from bees sent to the writer for diagnosis of the cause of the disease. It forms a tangled mass of mycelium on bees in a humid atmosphere.

MISCELLANEOUS FUNGI

Fusarium negundo Hubert (see Text Fig. 8). — It is interesting to note that this species of Fusarium occurs with considerable frequency within the alimentary canal of living bees and on dead bees, where it develops in the muscle tissues and in other soft tissues and at times spreads over the surface of the exoskeleton. It has been isolated from bees on several occasions during this investigation and has been cultured on synthetic nutrient agar and on blocks of wood of *Acer negundo*. On the latter substance the characteristic red stain appeared. Its only relation seems to be the cause of decay after the death of the bees. There seems to be little doubt that it is Hubert's species; it was sent to Hubert who recognized it as his species.

A number of other species of Fusarium occur commonly on bees, especially when the bees are on moist shaded ground about the apiary. They are found far less commonly on bees that die and remain within the hive during winter and spring and rarely on bees that die in dry situations outside the hive exposed to direct sunlight. None of the species of Fusaria are capable of extensive development on brood-combs, on honey or on pollen under conditions that usually prevail within the hive. They are concerned only with decay of the bees after death and are of no importance in beekeeping. Because of the taxonomic difficulties no attempt has

been made to determine the species identification of these organisms from bees.

Cladosporium herbarum Pers. (see Text Fig. 9). — What appears to be a form of this species has been isolated twice from bees during the past year. One culture was obtained from the mycelium within the abdomen of a bee and another from the mycelium and spores upon the outer surface of the exoskeleton. It is evidently

FIG. 9. CLADOSPORIUM HERBARUM Pers. *a*, conidiophores with chains of conidia; *b*, conidia; *c*, conidiophores showing usual method of arrangement; *d*, mycelium; *e*, anastomosing of mycelium; *f*, granulate mycelium

not of common occurrence on bees and does not grow on broodcombs under ordinary conditions.

Colonies on peptone agar are black-green, with a colorless margin, but without concentric rings, $\frac{1}{2}$ mm. high, surface powdery, aërial portion consisting of upright or ascending branched conidiophores. The reverse of the colony is blue-black to black and dark olive. The conidiophores are crowded, septate, brown, knotty, 3–4 μ in diameter, branched or less frequently unbranched, terminal cell usually slightly enlarged and club-like, blunt or tapering from the swollen portion towards the tip, containing an occasional

oil globule, wall smooth. The conidia are formed in branching chains, acrogenous, varying in size and shape, mostly egg-shape, commonly elliptical or short cylindrical, with rounded ends, a short extension of the exospore remaining on one end, wall covered with fine granulations, brown to golden-brown, mostly 6–10 (20) $\times$ $3\frac{1}{2}$–$4\frac{1}{2}$ (6) μ, one-celled, rarely two-celled. The mycelium is brown, mostly smooth but with sections covered with fine granula-

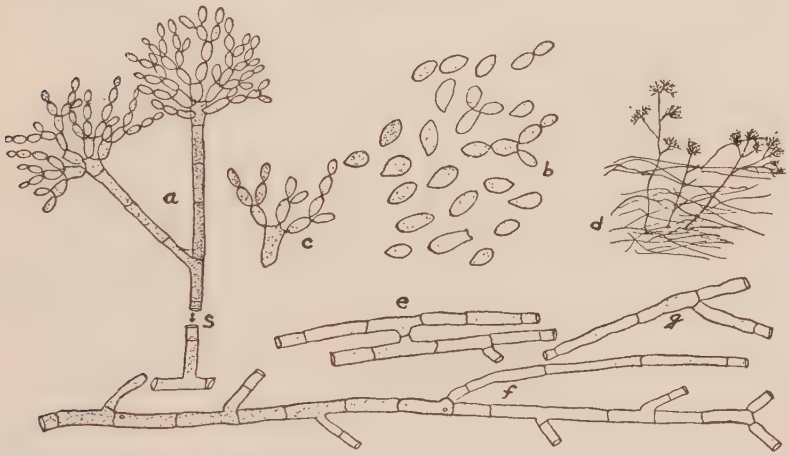


Fig. 10. Hormodendrum atrum Bonord. *a*, conidiophore with conidia, shortened at *s*; *b*, conidia; *c*, chains of conidia produced by branching of the original conidium; *d*, habit sketch of conidiophores; *e*, anastomosing of hyphae; *f*, *g*, mycelium

tions, closely septate, irregular, cells commonly dumb-bell shape or club-shaped, containing occasional oil globules, richly branched, lateral branches often short and composed of two or three cells, 3–6 (8) μ in diameter.

Hormodendrum atrum Bonord (see Text Fig. 10). — This fungus is of fairly common occurrence on bees and brood-combs. The writer has isolated it from the ventriculus of living bees, from mycelium on dead bees and from brood-combs. Ordinarily no damage is done by it since the mycelium does not spread extensively over the combs and growth on bees is saprophytic. In one instance, however, a hive of brood-combs that had been tightly closed and

stored in a loft was found to be extensively attacked by this organism.

Colonies on peptone agar are at first olive-green with a white margin, later dark green, gray-green to black, forming a thick spongy turf of aërial, trailing and creeping mycelium, all of which bear conidiophores. The conidiophores are upright or ascending, with or without short lateral branches, closely septate, smooth, terminal cell somewhat irregularly swollen, brown under the microscope, bearing about four or six conidia on the terminal cell from which branching chains of conidia develop, which are 3 to 4 μ in diameter, with an occasional oil globule. The conidia are formed in branching chains, acrogenous, ellipsoidal to spindle-shaped, occasionally short-cylindrical with rounded ends and with short terminal projections at the point of attachment, at first olive-green, becoming dull olive-green and finally dark gray-green, appearing nearly hyaline under the microscope, 5–6 (9) μ by 3–4 μ. The mycelium is closely septate, branched from the middle or end of cells, smooth, sometimes forked, hyaline at first, becoming golden-brown, smooth, containing few oil globules, mostly 3–5 μ in diameter. The reverse of the colony is blue-olive to black and brown.

Trichoderma Koningi Oud. (see Text Fig. 11). — In contrast with the common occurrence of *Trichoderma lignorum* on bees in Germany, as described by Fielitz (3), is to be noted the rarity with which members of this genus occur on bees in America. Two isolations of a species of Trichoderma, closely identifiable with *Trichoderma Koningi* Oud., have been made by the writer from bees and from brood of bees. This organism was first isolated from bees at Washington, D. C., during the summer of 1925. The softer tissues of infected bees were mummified and the mycelium had spread over the greater portion of the outer surface where an abundance of conidia had formed. The same species was isolated a second time from mummified larvae in capped cells of a moulded brood-comb which was sent to the writer (through the Bee-Culture Laboratory of the Bureau of Entomology) from Oregon. The greater number of the capped larvae in the sample were overgrown by the white mycelium of the fungus. Conidiospores had not

formed, but chlamydospores were present in small numbers. Larvae not yet capped and pupae were not attacked.

Colonies on Leonian's nutrient agar are at first hyaline and submerged or creeping, later rising at the edge of the culture dish and forming a ring of white cottony mycelium; this spreads inward

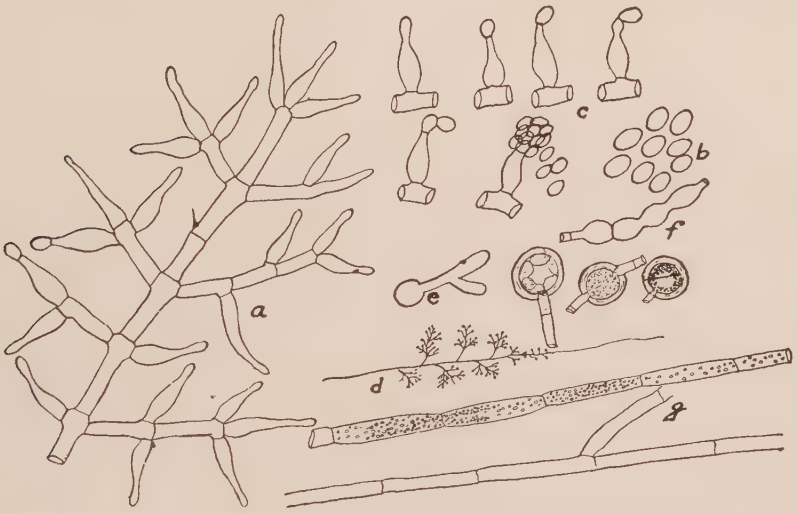


FIG. 11. TRICHODERMA KONINGI Oud. *a*, conidiophore; *b*, mature conidia; *c*, showing method of formation of conidia; *d*, habit sketch showing variation in complexity of conidiophores; *e*, germinating conidium; *f*, chlamydospores; *g*, mycelium

and with the development and maturation of conidia the turf in spots assumes shades of pale yellow, yellow, yellow-green and finally dark green (see Pl. II, Fig. 1). The conidiophores are simple or branched, upright or ascending, branching commonly opposite, forked or terminally whorled, septate, distinctly smaller in diameter than the mycelium on which they are formed, smooth and hyaline. The conidia are formed in succession by the swelling of the tips of the branches of the conidiophore and the simultaneous formation of a cross wall below the terminal swelling, separating soon after completion of the septum, slime-coated, forming heads of a few spores which break up readily in water or

after drying, at first hyaline and globose, becoming yellow and finally dark green and mostly oval to elliptical, 3–4 by 2.7–3.2 μ in size. Chlamydospores are formed, either intercalary or terminal, rarely in chains, globose, mostly 9–15 μ in diameter, wall much thickened, contents coarsely granular, or containing numerous oil globules, separated from the mycelium by a septum usually a short distance from the spore, hyaline. The mycelium is septate, smooth,

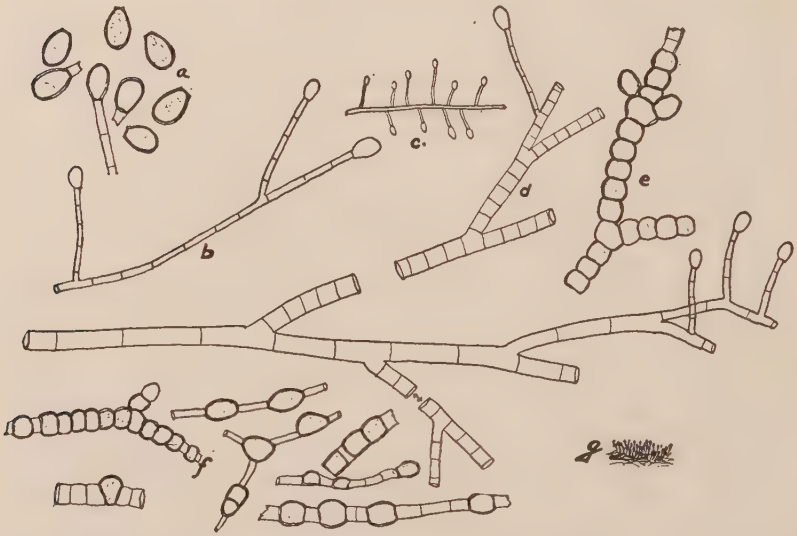


Fig. 12. Ovularia farinaecola, sp. nov. *a*, conidia, some of which have retained part of the conidiophore; *b*, fertile hyphae with lateral branches bearing conidia; *c*, showing habit of fructification; *d*, same as *c* except drawn on a scale about four times as large; *e*, *f*, types of chlamydospores; *g*, habit sketch

regular, hyaline, and contains numerous oil globules. The conidia-bearing cells are inflated at the middle, tapering towards the apex, or tapering from the base to the apex, and measure 6–15 μ by 1.5–2.5 μ.

This organism departs somewhat from the description of *Trichoderma Koningi* Oud., as given in Rabenhorst, *Kryptogamen Flora*, Auf. 2, Bd. 1, Abt. 8, p. 111. Chlamydospores are not mentioned

there and the conidiospores are described as not coated with slime. The other morphological characters are identical.

Ovularia farinaecola, sp. nov. (see Text Fig. 12). — Among the most common pollen fungi that occur on stored pollen in the spring in hives in which colonies have died during the winter and in hives occupied by weak colonies, is a species of the genus Ovularia. This fungus is limited in its development within the beehive to the pollen plugs. The mycelium spreads over the outer surface of the pollen plugs and penetrates the pollen more or less deeply. Only an occasional pollen plug may be affected or in extreme cases all the pollen in the brood-combs of a hive may be attacked by this fungus. The badly infected pollen is not used by the adult bees or fed to the brood, but is removed from the combs and carried out of the hive. Infected pollen soon becomes white and chalk-like and the surface assumes a white dusty appearance. A skin-like layer of mycelium at first forms over the surface of the pollen plugs which can be peeled off if care is used. The white plugs are readily noticeable and when infection is heavy a white line appears on the brood-comb corresponding with the location of the line of pollen surrounding the brood nest. This is shown in the accompanying photograph of a badly infected brood-comb (see Plate II, Fig. 2).

This fungus is not readily cultured. Spores placed on the nutrient agars used for culturing the other fungi considered in this investigation failed to germinate. Transplants of mycelium were likewise unsuccessful. It has been studied and illustrated from cultures on pollen plugs, where it grows, apparently free from other fungi. The description follows:

Colonies on pollen masses spread evenly over the surface, forming a closely adhering layer, pure chalk-white at first, sometimes becoming yellowish-white when old, submerged portion of closely crowded mycelium, aërial portion composed of conidiophores and creeping mycelium. The conidiophores are upright, closely packed, septate, hyaline, mostly 3–4 μ in diameter, varying considerably in length. The conidia are produced singly at the top of the conidiophores, rarely in short chains, cut off by a septum below the terminal swelling, hyaline or indistinctly pale green, refractive, wall double, portions of the conidiophore often remaining attached to

the spores, measuring 7–10 × 5–7 μ. Chlamydospores are formed abundantly on the mycelium, varying in shape, globose, oval, barrel-shaped, short-cylindrical, resembling the conidia, hyaline to indistinctly green, refractive, with double wall, mostly 5–10 μ in diameter.

Myceliophthora inflata, sp. nov. (see Text Fig. 13). — This organism was isolated from mycelium that had developed within the

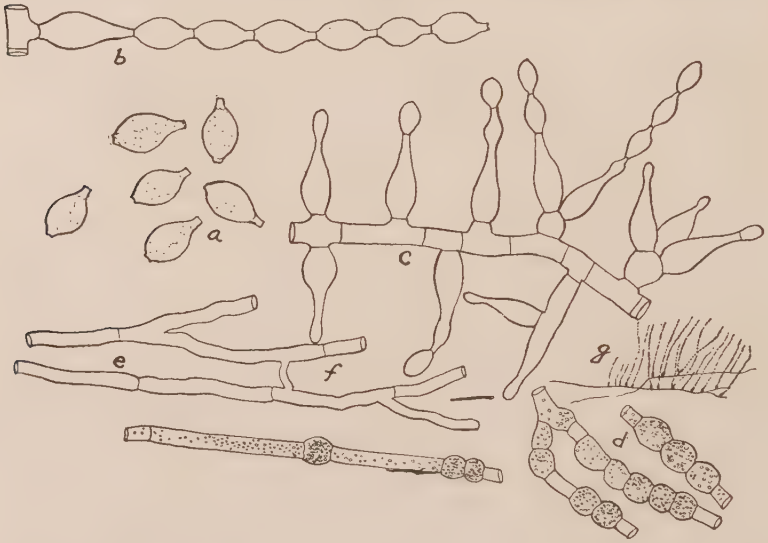


Fig. 13. Myceliophthora inflata, sp. nov. *a*, conidiospores; *b*, conidiophore with conidial chain; *c*, showing manner of formation of conidia; *d*, chlamydospores; *e*, mycelium; *f*, showing anastomosing hyphae; *g*, habit sketch of conidiophores and conidial chains

abdomen of an adult worker bee. It has been met with only once and is evidently of uncommon occurrence on bees. It grows slowly, although it is readily cultured on ordinary nutrient agars at room temperature.

Colonies on peptone agar spread over the surface, usually without concentric rings but with fan-shaped margins, less than 100 μ tall. Upper surface even or slightly elevated in the center of the colonies, pulverulent, at first chalk-white, losing bril-

liancy or assuming traces of buff with age. Reverse of colonies white to pale buff. The aërial portion of the colonies consists of creeping mycelium and conidiophores bearing chains of conidia, and the submerged portion of mycelium and chlamydospores. The conidiophores are simple or but little branched (forked, with a perpendicular branch or rarely terminally whorled), mostly inflated at the middle and flask-like, rarely not inflated and then the lower por-

Fig. 14. Sordaria fimicola (Rob.) Ces. & DeNot., *sensu* Griffiths. *a*, mature perithecium; *b*, group of asci; *c*, mature ascus enlarged; *d*, ascospores with gelatinous envelopes; *e*, apices of asci showing opening by pores; *f*, perithecia in various stages of development showing erumpent nature; *g*, habit sketch of perithecia; *h*, mycelium showing variation in diameter of hyphae

tion cylindrical and the upper portion tapering towards the apex, separated from the mycelium by a septum, otherwise not septate except that the branched conidiophores are septate at the origin of the branches, hyaline, 8–12 by 3–4 μ. Conidia lemon-shaped, with a short extension of the exowall on the lower end and a longer extension on the upper end; the short extension usually retains the septum, protoplasm confined to the central part of the spore, extension without protoplasmic contents, hyaline, $3\frac{1}{4}$–$3\frac{1}{2}$ by $2\frac{1}{2}$–$2\frac{3}{4}$ μ.

Chlamydospores are abundant on the old submerged mycelium, globose, subglobose, or oval, containing oil globules, separate or in chains, mostly 4–6 μ. Mycelium hyaline, sparsely septate, containing oil globules and distinct vacuoles, 2–4 μ.

Sordaria fimicola (Rob.) Ces. & DeNot., *sensu* Griffiths (see Text Fig. 14). — This organism was isolated from the mycosed thoracial muscles of an adult worker bee from a Florida apiary. All the wing and leg muscles of the bee were filled with mycelium but the abdominal muscles were not infected. This fungus is evidently of rare occurrence on bees since no other isolations of it have been made. It was isolated from a molded brood-comb by Miss Betts (1).

It grows well on Leonian's nutrient agar and forms perithecia early in the course of its development. The presence of a bacillus contamination was observed to stimulate the growth of perithecia near and on the contaminating colonies. A hypomycetous stage was not observed. The following is a description of this fungus as it appears on Leonian's nutrient agar: Perithecia scattered, erumpent or sunk in the substratum, rarely superficial, without a stroma but with loose wefts of mycelium surrounding the perithecia, black, glabrous, pear-shaped, ostiolate, ostiole circular, at the end of a short cone-shaped or cylindrical, curved or short-hooked neck, coriaceous-membranous, 270–450 μ in diameter. Asci cylindrical-clavate, tapering towards the base and to a much lesser degree towards the apex, with a round terminal pore, 190–220 μ by 12–16 μ. Paraphyses absent. Spores elliptical-fusiform with a barely perceptible terminal knob (appendage), olive-green when mature, surrounded by a gelatinous layer, 21–24 μ by 10–12 μ. Mycelium hyaline-olive, richly septate, varying from 2 to 12 μ in diameter.

In addition to the species of fungi that have already been discussed in this paper, forms of a number of other genera have been isolated with varied frequency from bees and from brood-combs. Among the most common of these are species of the genus Alternaria. Small amounts of mycelium of these organisms occur on bees and less frequently on brood-combs, and spores of *Alternaria spp.* have been observed with regularity within the alimentary canal of worker bees. A variety of organisms recognizable as belonging to

the genus Monilia have also been isolated from both bees and brood-combs, but no damage is done by them. Other genera represented by the fungi isolated from bees or combs during this investigation were Cephalosporium, Oidium, Oospora, Helminthosporium, Exoascus, Saccharomyces, Mycoderma and Torula.

The writer is indebted to Dr. C. H. Kauffman of the University of Michigan for helpful suggestions and criticisms during the course of this investigation. I desire likewise to express my appreciation to Dr. Charles Thom and Margaret B. Church of the Bureau of Chemistry for aid in determining the identity of species or in arriving at the concepts of the specific names of Penicillium and Aspergillus given in this paper, and to J. I. Hambleton of the Bureau of Entomology for valuable assistance in the collection of fungi herein considered.

University of Michigan

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PLATE II

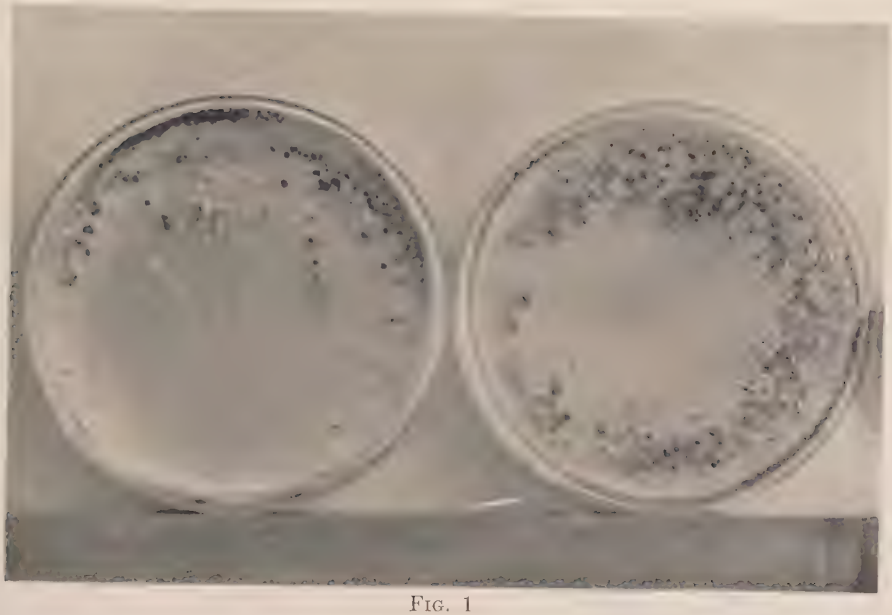


FIG. 1

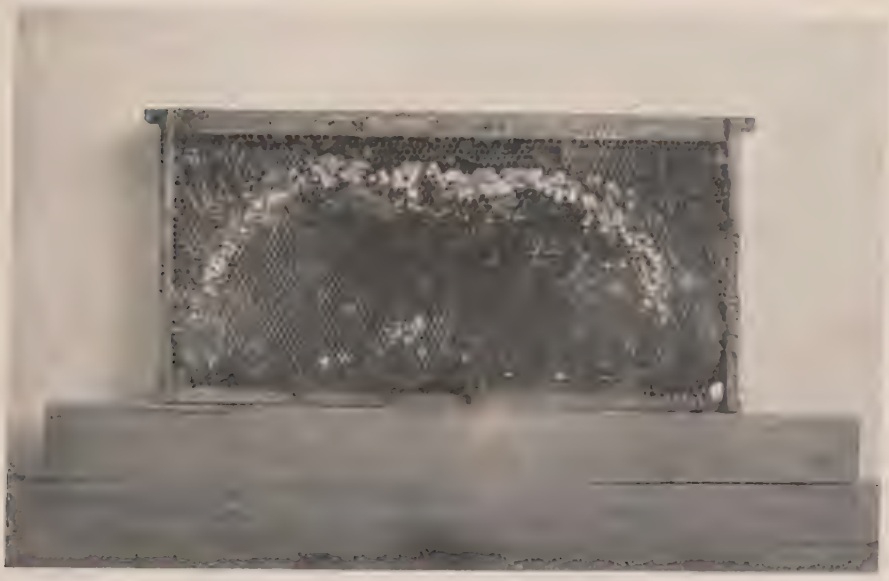


FIG. 2

AN ECOLOGICAL STUDY OF LINNÉ BOG, CHEBOYGAN COUNTY, MICHIGAN, WITH SPECIAL REFERENCE TO *NEMOPANTHUS MUCRONATA* (L.) TRELEASE *

DORIS DEAN AND HELEN COBURN

LINNÉ BOG is a small peat bog in Cheboygan County, Michigan, formed in a depression about 90 meters by 70 meters, in a glacial moraine that was originally covered with beech-maple forest. For the most part the bog is an example of the Chamaedaphne stage in bog development, with small patches of Carex present on the mat and with Nemopanthus invading the periphery, as shown on the accompanying map (Map 2; see also Pl. III, Fig. 1). There is no apparent inlet or outlet, nor perceptible drainage in the bog area. Except in wet seasons the bog is fairly dry, and there is no open pool of water.

HISTORY

Not much is known concerning the history of Linné Bog. It came under the observation of the University of Michigan Biological Station for the first time in 1916. At that time there were open pools of water winding irregularly on the mat. Chamaedaphne grew to the edge of the pools. In 1921 the pools had been invaded by *Eriophorum viridicarinatum*, which later entirely gave place to Carex.

It was learned from a farmer owning the land on which the bog is located that the virgin forest of mixed beech, maple and a few

* Contribution from the Biological Station of the University of Michigan.

The work at Linné Bog was done under the direction and supervision of Professor F. C. Gates during the summer of 1926. Dr. C. D. La Rue assisted in the study of the anatomical structure of *Nemopanthus mucronata*.

pines was not lumbered until 1911. Prior to that time the bog area was a small lake two feet deep, which afforded a breeding place for ducks. No Thuja or Picea has ever been found in or near the bog. In 1919 a fire burned in the bog area, traces of which are still seen in the upland on the charred stumps and logs.

PRESENT CONDITIONS

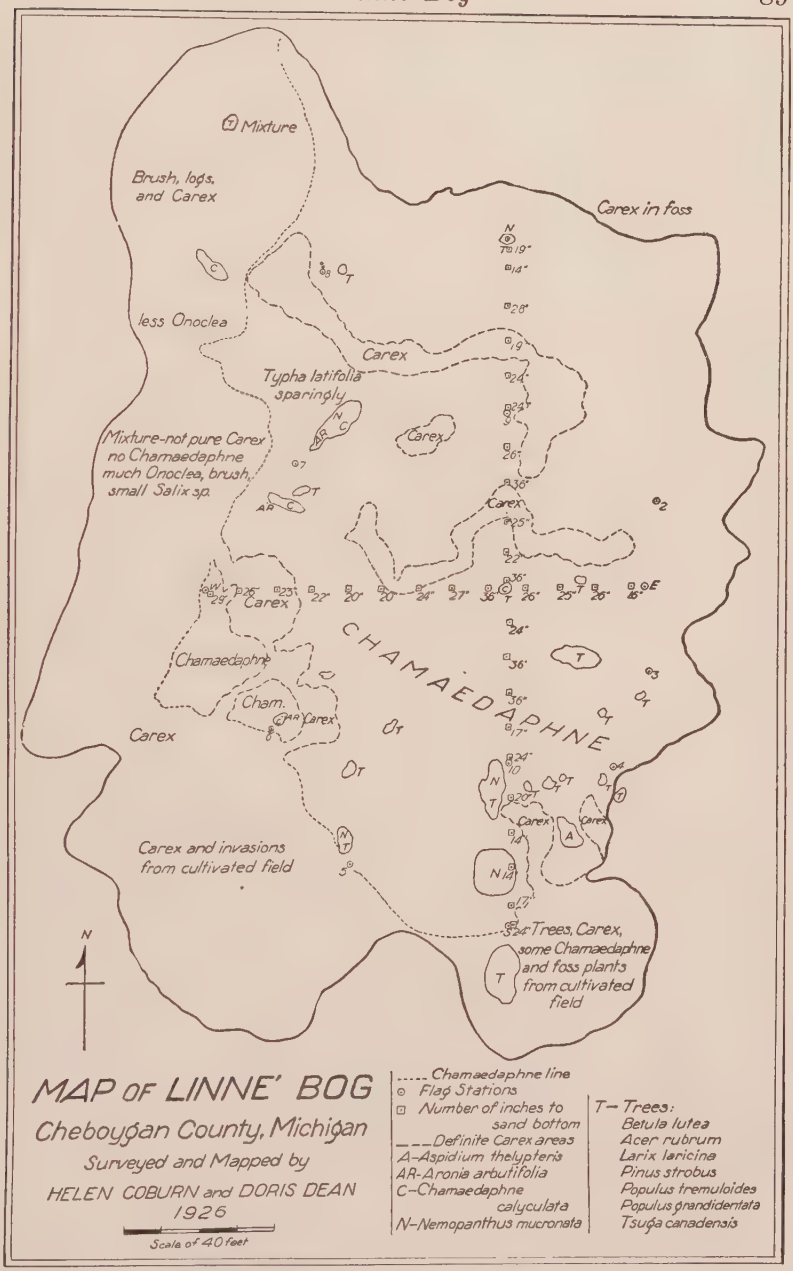
The ridge surrounding the bog is now covered with a tree growth, chiefly aspens, but charred stumps and logs still remain in the area as evidences of lumbering and fire. Some of the largest stumps were found to the east of the bog, the largest, a stump of *Pinus resinosa,* measuring 1.03 meters in diameter 61 centimeters from the ground.

Although aspens far outnumber any other kind of trees, several other genera are represented in the fringe of trees around the bog rim. These include a few *Betula papyrifera,* still too young to have the characteristic white paper bark. Small Salix shrubs of three species, *S. lucida, S. rostrata* and *S. serissima,* are scattered fairly evenly in the area, but are growing nowhere in dense clumps. *Acer rubrum* seedlings are less numerous than the Salix shrubs. An occasional tree of *Ulmus americana* and *Fraxinus nigra* was observed to the northeast and southwest respectively. This tree area, which does not extend more than forty-five meters from the bog foss, is narrower than that in most places, and at the southwest there is an opening where the band of trees around the bog rim is broken. Beyond the trees at the east, north and west are shrubby pasture lands; to the south, cultivated fields. The character of the ground flora of the tree area has been somewhat influenced by the proximity to cultivated fields.

VEGETATION

The vegetation of Linné Bog may be divided into the following associations:

A. Mat
   Carex association
   Chamaedaphne association
B. High Shrubs
   Nemopanthus-Ilex association



MAP 2. Linné Bog, showing distribution of the plant associations, 1926

The Carex association is represented by distinct areas irregularly placed on the mat and giving the general appearance of what might have been the course of a winding pond. In the southeast the Carex of the Chamaedaphne mat extends through a narrow channel in the Chamaedaphne, forming a bay where it is mixed with trees and plants that have spread in from the bog foss (see Map 2).

The most extensive Carex area lies in the southwestern part of the bog beyond the Chamaedaphne line between Stations 5 and 6. The high shrubs are absent and the Carex extends to the edge of the bog. Here there is no apparent foss and, with the exception of an occasional shrub and a few clumps of Chamaedaphne, the area is open and level, without the hummocks which are characteristic of the rest of the bog.

Between Stations W and 8, Carex widens out beyond the Chamaedaphne margin to a larger Carex area, which is a mixture of *Carex sp.*, *Onoclea sensibilis*, *Salix spp.*, and a few trees but no Chamaedaphne. This area extends behind the high Ilex shrubs north of Station 8. It is not a pure Carex association but Carex is still persisting and is the dominant ground plant, growing up among fallen logs and brush. Onoclea is less abundant than between Station W and 7, and the high bog shrub is more dense.

Chamaedaphne is rapidly invading the Carex areas located on the Chamaedaphne mat, though the Chamaedaphne shoots are still too small to overtop the Carex (see Pl. III, Fig. 2). In typical Carex area fifty quadrats each one square meter in size were taken, but in only a few of these quadrats was there an absence of Chamaedaphne.

FREQUENCY INDICES OF PLANTS IN THE CAREX ASSOCIATION

Carex retrorsa	100	Epilobium adenocaulon	20
Chamaedaphne calyculata	60	Moss	8
Carex lasiocarpa	40	Dulichium arundinaceum	6
Bidens connata	40	Scirpus atrocinctus	4
Potentilla palustris	24	Lycopus americanus	4

The bog mat is almost entirely covered by *Chamaedaphne calyculata*, healthy and not infested as Chamaedaphne is in some other bogs in the region. At the time the upland and ridge surrounding the bog were lumbered, logs varying in length from six to nine meters fell in the pond. Upon these logs the Chamaedaphne invaded and filled the bog rapidly. A hummocky appearance is given to the bog by the logs underlying the present vegetation. On these logs Chamaedaphne shows the most vigorous growth, the greatest stem diameter and height.

Chamaedaphne fills the slight depression between hummocks, but it is in these depressions where mosses, other than Sphagnum, and algae are found, and where at the beginning of the summer season there may be from five to ten centimeters of water. Toward the end of summer the moist areas become dry, leaving a crusty formation upon the surface.

Carex is very sparingly present with the Chamaedaphne in depressions between hummocks, but was never found in the higher clumps of Chamaedaphne. There is an abundance of Sphagnum growing with the Chamaedaphne except in places where Chamaedaphne has just recently invaded the Carex association. In a place between Stations 3 and 4, where it was extremely moist at the beginning of the season, there was a large patch of *Mnium punctatum*. *Nemopanthus mucronata* and *Aronia arbutifolia* are invading the Chamaedaphne, but are not yet well established at any one place. A count made of plants noted in fifty quadrats, taken on a line from north to south, including only typical Chamaedaphne areas, gave the following frequency indices:

FREQUENCY INDICES OF PLANTS IN THE CHAMAEDAPHNE ASSOCIATION

Chamaedaphne calyculata	100	Nemopanthus mucronata	4
Sphagnum sp.	90	Potentilla palustris	4
Mosses	80	Aronia arbutifolia	2
Carex retrorsa	30	Gaylussacia baccata	2
Andromeda glaucophylla	6	Vaccinium canadense	2
Carex lasiocarpa	4		

On the bog mat are a few trees ranging in height from one to six meters, with the taller trees near the outer margin of the bog mat. Seedlings of *Acer rubrum* and *Betula lutea* are more numerous than seedlings of other species. A single *Larix laricina* and *Tsuga canadensis*, the latter scraggly and in an unhealthy condition, are on the mat at the northeastern end. No seedlings of *Pinus strobus* have yet invaded the mat though near its margin are three trees, one measuring 19.4 centimeters in diameter.

Beyond the Chamaedaphne association is the high bush thicket which completely surrounds the bog except between Stations 5 and 6, where the Carex association opens out into the upland. *Ilex verticillata* and *Nemopanthus mucronata* are the dominant bushes in the high shrub association. Most of these shrubs are from two and a half to three meters high and form a dense thicket.

Nemopanthus mucronata with *Aronia arbutifolia* are invading the Chamaedaphne mat, while Ilex is the chief shrub in the outer thicket and has not spread inward from there. Aronia is infested and seems to be dying out.

Surrounding the high shrub thicket is a foss with a mixture of vegetation, logs and brush (see Pl. III, Fig. 3). During the wet season the foss is very moist, with a great amount of algae growing in it and mosses clinging to the fallen logs. The character of its ground flora has been influenced by the adjacent cultivated fields.

Peat readings were taken on the Chamaedaphne mat at intervals of three meters on lines connecting Stations N and S, and E and W. The distance from the surface of the bog mat to pure sand was not uniform in the bog area and did not become progressively greater toward the center of the mat. On hummocks the distance to sand varied from forty centimeters to ninety centimeters, in Carex areas from forty-eight centimeters to seventy-one centimeters. There was no mucilaginous peat except in one sample, and that felt only slightly sticky. Samples of peat contained no shells, no blue clay, nor charcoal. Peat from the more depressed areas was quite moist, but all samples taken were of solid peat with plant fibers, roots and leaves well

decayed, or merely blackened and with plant structures evident. There was no correlation between depth at which sample was taken, or depth to sand, and the moisture content and degree of decay of plant fibers. Sand underlying the peat was of two types, a fine-grained white sand, and a light brown gritty sand containing pebbles.

LIST OF HIGHER PLANTS IN LINNÉ BOG

M denotes species present on the mat; F, species present in the foss; U, species present in the upland.

Acer pennsylvanicum L. .....U
Acer rubrum L. .....M F U
Anaphalis margaritacea (L.) Benth. & Hook .....U
Andromeda glaucophylla Link. ...M
Apocynum androsaemifolium L. .U
Aralia nudicaulis L. .....U
Aronia arbutifolia (L.) Ell. . M F
Betula papyrifera Marsh. .....F
Betula lutea Michx. f. ..... M F
Bidens connata Muhl. .....M
Carex lasiocarpa Ehrh. .....M
Carex retrorsa Schwein. .....M
Carex sp. .....M F U
Chamaedaphne calyculata (L.) Moench. ..... M F
Cirsium arvense (L.) Scop. ....F U
Cornus stolonifera Michx. ..... F
Dryopteris thelypteris (L.) A. Gray ..... M F
Dulichium arundinaceum (L.) Britton .....M
Epilobium adenocaulon Haussk. .....M
Epilobium angustifolium L. ....M U
Equisetum sp. .....F
Fragaria virginiana Duchesne. ...U
Fraxinus nigra Marsh. .....U
Galium trifidum L. .....M
Gaylussacia baccata (Wang.) K. Koch. .....M F
Hypericum virginicum L. .....F
Ilex verticillata (L.) A. Gray ....M
Impatiens biflora Walt. .....F
Lactuca canadensis L. .....U
Larix laricina (Du Roi) Koch. .M F
Lycopus americanus Muhl. ...M F
Menyanthes trifoliata L. .....M F
Mosses .....M F U
Nemopanthus mucronata (L.) Trelease .....M
Onoclea sensibilis L. .....M
Osmunda regalis L. .....M F
Pinus resinosa Ait. .....F
Pinus strobus L. .....M F
Poa palustris L. .....U
Populus grandidentata Michx. . .M U
Populus tremuloides Michx. . .M U
Potentilla palustris (L.) Scop. .M F
Pteris aquilina L. .....U
Ribes triste Pall. .....M F
Rubus allegheniensis Porter .....U
Rubus strigosus Michx. .....U
Rumex sp. .....F
Salix lucida Muhl. .....M F U
Salix rostrata Richards .....M F U
Salix serissima (Bailey) Fernald .....M F U
Scirpus atrocinctus Fernald .....M
Scutellaria lateriflora L. .....M
Solidago canadensis L. .....U
Sphagnum sp. .....M F
Trifolium repens L. .....U
Tsuga canadensis (L.) Carr. M F U
Typha latifolia L. .....M
Ulmus americana L. .....F
Vaccinium canadense Kalm. . .M F
Vaccinium pennsylvanicum Lam. .....M F
Vaccinium oxycoccus L. .....M
Verbena hastata L. .....M
Verbascum thapsus L. .....U
Viola sp. .....F

ECOLOGICAL STUDY OF *NEMOPANTHUS MUCRONATA* (L.) TRELEASE

A special study was made of *Nemopanthus mucronata* in Linné Bog, checked by observations of the same species in two other bogs and a filled-in beach pool, all in the same region. Nemopanthus is a much-branched shrub with smooth ashy gray bark, and ranges in height from two to five meters. The leaves are elliptical, entire or very slightly toothed, mucronate at the tip, bluish-green, changing to yellowish-green when the fruit is ripening. Fruit of Nemopanthus is a bright purplish-red drupe borne on a slender pedicel. As soon as a clump of Nemopanthus shrubs is well established on the bog mat or with other shrubs, here Ilex, of the high bog shrub association, the outer shoots bend forward giving the appearance of a well rounded crown formed by shrubs of unequal height.

Nemopanthus plants were dug up in:

(*a*) Linné Bog, a Chamaedaphne bog with mat well grounded;
(*b*) Bryant's Bog, a Chamaedaphne bog with quaking mat;
(*c*) Chamaedaphne-Larix, a Chamaedaphne bog near Big Stone Bay, with a grounded mat;
(*d*) Deer Point, a beach area that was formerly a beach pool, but is now well above the lake level and dry.

The general appearance of Nemopanthus and the manner of root growth were unmodified by these different habitats. In Linné Bog the underground stems of Nemopanthus were covered by ten centimeters of Sphagnum and partly decayed Chamaedaphne leaves. When enough of the surface substance was removed so that plants could be pulled, there was often a sudden snapping of the horizontal underground stem at a node. Chamaedaphne roots do not prepare a course for Nemopanthus roots to follow, but roots and underground stems of both plants are so interlaced that it is difficult to separate them. Stolons from the underground stem of Nemopanthus grow horizontally several centimeters before bending upward. Vertical shoots occur in some of them at intervals of from seven to twenty centimeters; the longest interval noted was seventy-eight centimeters.

A trench seventy-eight centimeters deep was dug around a clump of seven shoots. The Sphagnum in which the underground stems and roots of Nemopanthus and Chamaedaphne formed a network was moist and contained bits of partially decayed roots, twigs and leaves, but no peat. Some of the roots extended into the peat which at this place was twenty-three centimeters below the surface and formed a layer fifteen centimeters deep. White sand was reached at a depth of thirty-eight centimeters and contained a very few living root fibers. In brown sand below the white sand there was no trace of plant life. Roots occurred most numerously at bends in the underground stem; the longest one measured was seventy-four centimeters. Sections of many of the roots of Nemopanthus as well as Chamaedaphne had a crinkled appearance.

Cross-sections of Nemopanthus stems and roots studied revealed no unusual anatomical structure. The wood is like that of most hollies, fine-grained and of uniform structure. Before cork, which develops early in uniform layers, is formed, the young roots are protected from loss of water by a heavily cutinized epidermis. There is an absence of root hairs, but their function is performed by mycorrhiza. The plant grows slowly; a ten-year old stem measured two centimeters in diameter; a shoot three meters high had a diameter of three and six tenths centimeters.

SUMMARY

1. Linné Bog, an upland bog in Cheboygan County, Michigan, about ninety meters in diameter, is an example of a Chamaedaphne stage in bog development.

2. The presence of a few fairly large trees and stumps near the outer margin of the bog indicates that at the time the surrounding forest was removed by lumbering, the trees extended nearly to the open water.

3. Plants have been introduced into the foss and Carex area of the southwestern part of the bog from the cultivated fields to the south, but there has been no trace of *Thuja occidentalis* in or near the bog.

4. The few trees now on the mat have grown from stumps at the edge or are seedlings which are found with Chamaedaphne on decaying logs.

5. The peat is solid and contains only plant remains, mostly well decayed.

6. *Nemopanthus mucronata* is the only shrub of the high bog shrub association invading the Chamaedaphne; the study of cross-sections of roots and stems revealed no unusual anatomical structure.

University of Michigan Biological Station
Cheboygan, Michigan

EXPLANATION OF PLATE III

The photographs were taken in 1926

Fig. 1. From the south edge northward across the central part of Linné Bog, Carex areas appear lighter in color than Chamaedaphne areas

Fig. 2. Central portion of Linné Bog, showing Carex in foreground, Chamaedaphne, Nemopanthus and trees in background

Fig. 3. Foss at Linné Bog near Station 1

PLATE III

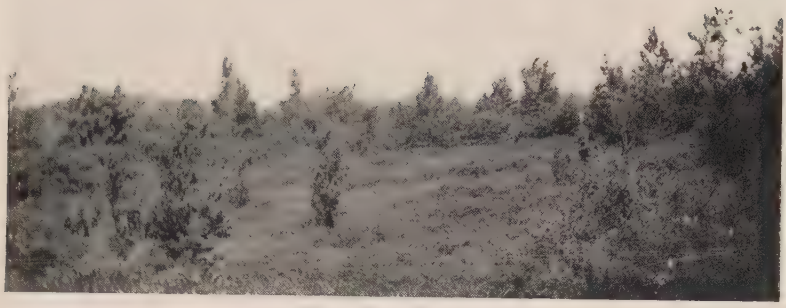


FIG. 1

FIG. 2

FIG. 3

THE MORPHOLOGY AND CYTOLOGY OF PERFECT FLOWERS IN *POPULUS TREMULOIDES* MICHX.*

EILEEN WHITEHEAD ERLANSON AND
FREDERICK J. HERMANN

A FULL-GROWN tree of *Populus tremuloides* Michx. was observed by the junior author in the spring of 1926 in which shrivelled remnants of stamens were persisting in the fruiting catkins at the base of nearly all the developing ovaries.

The tree, which was about fifteen feet high, was growing beside a small run-off at the foot of a gravelly morainic hill east of Ann Arbor, Michigan. Except for the presence of stamens among the fruit, the specimen differed in no way from the common aspen which abounds in the immediate region. The only other poplars on the neighboring hillsides were *Populus grandidentata* and *Populus deltoides*.

At the end of February, 1927, twigs of the anomalous tree, as well as from normal dioecious specimens of aspen, were brought into the laboratory, where they quickly flowered in jars of water.

MORPHOLOGY

The male and female organs of the hermaphrodite tree are all perfectly normal, with the gynoecium situated terminally on the axis of each flower and the stamens attached to the inner walls of the cup-like disc, laterally to the axis and, for the most part, on the anterior side of the ovary (Pl. IV, Figs. 1–3). Each stamen is free with a normal filament and anther. No monstrosities have been observed, such as stigmas on anthers or anthers

* Paper from the Department of Botany of the University of Michigan, No. 259.

on the carpels, like those found by Chamberlain in *Salix petiolaris* (3). Shimek (11) reported a *Salix amygdaloides* with perfect flowers, and Engler and Gilg (4) mention the *Salix Medemii* of Persia as being occasionally monoecious and rarely hermaphrodite; but no reference to a Populus bearing almost entirely regular ambisporangiate flowers has been found. The nearest approach to this condition was reported by Hastings (6), who found catkins of a tree of *Populus grandidentata* bearing perfect flowers on some of its branches only, while varying degrees of abnormality were exhibited in many of these.

The number of stamens per flower varies and counts were made in nearly one thousand flowers. Since we are here dealing almost entirely with perfect flowers, we are forced, according to definition, to speak of the inflorescence in this specimen as a spike instead of as an ament or catkin. Table I A shows the distribution of stamens in flowers of individual spikes, while Table I B shows the distribution in the total number of flowers counted.[1] A very few flowers (about 1 per cent) are entirely male; these are situated at the proximal end of their respective spikes. A much larger number (approximately 17 per cent) are female only; these occur at the distal end of the inflorescences. There is also a marked tendency for the flowers at the upper end of the spikes to have fewer stamens than those at the base and vice versa.

[1] The average number of stamens in the flowers of normal male trees is larger than in the perfect flowers. Out of ten flowers from a dioecious tree, four had 13 stamens; one had 12; two had 10; two had 9; and one had 8.

TABLE I A

DISTRIBUTION OF STAMENS IN FLOWERS OF INDIVIDUAL SPIKES

Spike No.	Staminate	Number of Stamens								Pistillate	Total No. of Flowers in Spike
		8	7	6	5	4	3	2	1		
I	2	—	—	—	—	8	17	12	23	14	76
II	—	—	—	—	1	5	16	18	16	23	79
III	—	—	—	—	—	1	9	14	22	26	72
IV	—	—	—	1	6	9	11	18	9	22	76
V	—	2	—	2	10	32	34	9	2	2	93
VI	—	—	1	1	—	19	29	22	7	4	103
VII	—	—	—	2	4	19	22	15	11	7	80
Total	2	2	1	6	21	93	138	108	90	98	579

TABLE I B

DISTRIBUTION OF STAMENS IN TOTAL NUMBER OF FLOWERS EXAMINED

Staminate	Number of Stamens								Pistillate	Grand Total
	8	7	6	5	4	3	2	1		
9	2	2	10	34	160	247	169	153	168	954

The gynoecium consists of two carpels with parietal placentation of the anatropous ovules, as described by Graf (5) for other species of Populus. Our specimen is protandrous; the megaspore mother cells usually are in prophase of meiosis when pollen grains or tetrads are present in the anthers.

Male Gametophyte

The pollen grains are spherical and average about 37.5 μ in diameter. Out of fifty grains measured, one was exceptionally large, 72.5 μ; eight measured between 50 μ and 45 μ; nine between 45 μ and 40 μ; thirty between 40 μ and 35 μ; and two between 35 μ and 30 μ. Approximately 14.3 per cent of the pollen consists of dwarf spherical grains averaging 22.5 μ in diameter.

The pollen of a normal male aspen is markedly smaller in diameter than the large grains of the perfect form, the average being 27.5 μ. Dwarf grains are found very rarely if at all in this pollen.

When the pollen of the perfect flowers was placed in a 3 per cent sugar solution thickened with gelatin the grains burst, but in a 1.5 per cent solution, or even in pure water, almost all the large grains and several of the dwarfs germinated.

It is significant that, while the pollen proved to be very effective in self-fertilization, it failed to give any fertilization in several attempted crosses with normal female flowers of the same species.

The Embryo

Unfortunately all our material was fixed at stages either too early or too late to show good embryo sacs, so that it could not be determined whether they correspond with those described by Graf for Populus or not.

The perfect flowers, which opened in the laboratory, were selfed and the developing ovaries were fixed in medium chrom-acetic, cut at 10 μ, stained with iron-alum-haematoxylon or with Flemming's triple stain, and examined for embryos. Normal young embryos were observed between the synergid nuclei at the micropylar end of several embryo sacs; one was at the two-celled stage (Pl. IV, Fig. 4), and others further advanced in development. No signs of nucellar buds in the embryo sacs were observed. It is well known that *Populus tremuloides* is not very fertile; in some parts of its range it seems never to reproduce by seed but only vegetatively (1).

Seedlings

Some of the selfed seeds were planted. They germinated immediately, but it will probably be several years before it will be known to what extent they have inherited their parent's floral characters.

CYTOLOGY

Since it has been shown by Blackburn and Harrison (2), and also by Meurman (8), that there is an unequal chromosome pair in the pollen mother cells of some dioecious Populus species, the nature of the sex-chromosome group in a form with perfect flowers is of particular interest.

Material and Methods

Flowering twigs of the hermaphrodite form, and also of normal male and female trees, were brought into the laboratory, and as soon as the inflorescences emerged from the bud scales they were fixed, after all the hairy bracts had been carefully pulled out by hand. Both Carnoy's fluid and Flemming's strong fixative were used and gave equally good results, although the former caused more shrinkage in the young tetrad stage. After the sections had been embedded in paraffin, they were cut at 12–13 μ. Iron-alum-haematoxylon gave a very satisfactory stain. Complete series of stages throughout reduction division were obtained only in the pollen mother cells of the perfect flowers and of normal male flowers.

Dioecious Male Flowers

The pollen mother cells of a normal male tree of *Populus tremuloides*, growing near the ambisporangiate specimen, show clearly eighteen pairs of autosomes and an unequal sex pair at metaphase of the first reduction division (Pl. V, Figs. 6–7). The autosome pairs range in size from one large or giant pair through two varying sets of medium-sized and small pairs. Thus *Populus tremuloides* closely resembles in its chromosome complex not only the related *P. tremula* of Eurasia (2), but also *P. trichocarpa* and *P. balsamifera* (8), all of which have the giant pair and

seventeen small pairs of autosomes varying in size, as well as an unequal sex pair of the XY-type in the male.

The sex pair is easily picked out in most of the metaphase plates as well as in profile views of the heterotypic spindle (Pl. V, Fig. 8), where it usually lies on the periphery of the equatorial plate, as found by Meurman in other species of Populus. The X-chromosome is very long until after the heterotypic anaphase is past and resembles very closely that figured for *Populus trichocarpa* by Meurman. No anaphase was found in which the members of a sex pair lagged markedly behind the other pairs in passing to the poles. Reduction division, in most of the specimens observed, takes place regularly; one or two pairs of autosomes sometimes lag behind the others at both anaphases. Normal tetrads of pollen grains are formed.

Perfect Flowers

One good heterotypic metaphase plate obtained in a megaspore mother cell of a perfect flower shows (Pl. V, Fig. 9) that there are eighteen pairs of autosomes (including a giant pair) and an unequal XY-pair. Later stages were not found in the megaspore mother cells.

The first striking characteristic of the pollen mother cells in the anthers of the perfect flowers is the irregularity with which the different anthers undergo reduction; contiguous anthers may contain pollen mother cells in prophase and tetrads. In the normal male catkins reduction begins in the stamens at the base of the inflorescence and continues regularly to the apex. Once the sporogenous cells in a pollen sac of the perfect flowers enter upon meiosis, all the cells in the sac synchronize except in the last stages.

The study of the chromosomes throughout reduction division is rendered somewhat difficult by the frequent presence of dark staining-bodies in the cytoplasm. These may be scattered throughout the cell, or only two or three may be present just outside the spindle area. Because these bodies are often about the same size as the smallest autosomes, they make it difficult to get counts at the telophases particularly; they are shown in

some of our figures (Pl. V, Figs. 7, 12) and are present in both the perfect-flowered and the dioecious types. In Figure 7 two such bodies are shown lying beside a first metaphase plate in a normal male flower; they are at a level slightly different from that of the nineteen pairs of chromosomes. Metaphase plates are often found with nineteen clearly observable pairs of chromosomes (Pl. V, Figs. 9, 11) and nineteen pairs are also found at diakinesis, so that we can confidently say that the haploid chromosome number in both forms of *Populus tremuloides* is nineteen. It has not yet been possible to make a somatic count; in somatic divisions found in the floral parts the chromosomes often present a beaded appearance, which, together with their size variations, render correct counts very difficult. We are trying to obtain root tips for this purpose.

At diakinesis in the pollen mother cells nineteen pairs are found (Pl. V, Fig. 10); the members of the pairs are closely applied to one another and it is not possible to distinguish the sex pair; this, however, becomes evident at metaphase of the heterotypic division, where it is found on the periphery of the equatorial plate (Pl. V, Figs. 11–12). The X-member of the pair is very long at metaphase and its free end is usually bent at right angles to the axis of the spindle; this bent portion comprises about one third of its length and the spindle fibres are attached at the bend. The small Y-chromosome is attached to the opposite end of the X-chromosome by its side, so that it lies at right angles to the spindle too. All this is likewise true of the sex pair in the normal male flowers. The sex pair is seen alone in a cut cell at first metaphase in Figure 13; here the X-chromosome is seen to be more condensed and somewhat two-lobed. The resemblance between the sex pair in the perfect flowers and in the normal male flowers is very close; the chief difference seems to be the reluctance of the X- and Y-chromosomes to part at the heterotypic anaphase in the former. The cytological evidence at reduction division does not lead us to suspect that there has been non-disjunction between the XX-pair in the egg which produced the hermaphrodite tree, for although the X-chromosome tends to become somewhat bipartite on the

heterotypic spindle, it is no larger than the X-chromosome at similar stages in a normal male flower. The perfect flowers seem to possess an XY-pair such as is typical of the normal male in Populus.

At heterotypic anaphase the sex pair may behave normally, one member going to each pole (Pl. V, Fig. 14), or the entire pair may be found at one of the poles while the autosomes are on the equator in early anaphase (Pl. V, Fig. 15). At this stage also one or two pairs of chromosomes are sometimes to be found in the cytoplasm, having failed to reach the spindle. Figure 16 shows a strange condition of affairs, the XY-pair lying at one pole of an heterotypic meta-anaphase spindle and both members of what is apparently the giant pair of autosomes being at the opposite pole. Whether these pairs passed entire to the poles along the spindle, or whether they failed to reach the metaphase plate after diakinesis, is not known. The latter is perhaps the more plausible explanation; some factor may be present which reduces the motility of the largest chromosomes so that they are left behind. Regular heterotypic anaphases are often found, although a few pairs of autosomes sometimes lag, or streaks of chromatin material are left between the chromosome groups as they pass to the poles (Pl. VI, Fig. 17). The sex pair has not been observed lagging in heterotypic anaphase, as it so often does in dioecious plants (8); Meurman also states that it does not lag in *Populus balsamifera* either. Upon reaching the pole the X-chromosome condenses and can no longer be picked out with certainty. It is of interest to note that one of the smallest of the autosome pairs is often situated near the XY-pair at first metaphase. Occasionally the members of the pairs begin separating and passing to the poles as soon as the nuclear membrane dissolves after diakinesis.

Interkinesis nuclei are formed in which chromosome counts can be made. At this stage the irregular distribution of the chromosomes to the daughter nuclei at the heterotypic division becomes clearly evident. Figure 18 shows two uncut interkinesis nuclei in the same cell, a large one with twenty-one chromosomes (including possibly a pair of homologous chromosomes) as well

as three nucleoli; the smaller nucleus is distorted and has fourteen chromosomes and one nucleolus with one chromosome lying just outside the nuclear membrane. Twenty interkinesis nuclei showed the following distribution of chromosomes: 21–14 (1 in cytoplasm); 21– ; 19– ; 14–13 (including both the giant autosomes); 19–14 (2 in cytoplasm); 19– ; 20– ; 18–15; 20– ; 18– (extra chromosomes in cytoplasm); 16– ; 18– ; 7– ; 20– ; 19– ; 7– .

The homeotypic division may proceed regularly or there may be a slight amount of lagging at anaphase. Small extra spindles are sometimes seen, on which the chromosomes which have been left out of the interkinesis nuclei divide (Pl. VI, Fig. 19). A few extreme cases are found in which the second division fails altogether; the chromosomes become distorted and clump together and the chromatin forms irregular masses along the spindle (Pl. VI, Fig. 20). Such conditions are found in cells that have lagged behind the others during reduction, so that a few irregular homeotypic anaphases sometimes occur among cells that have reached the tetrad stage. Such cells as that shown in Figure 20 fail to develop any further and can be found as irregular protoplasmic masses among the young pollen grains before these are shed. In the tetrad stage polyspory is common; five or six pollen grains are often found within one mother cell-wall, instead of the normal four (Pl. VI, Fig. 21). Figure 5 shows a group of young pollen grains of various sizes, a state of affairs which is to be expected as a result of the irregular distribution of chromosomes found throughout reduction division.

DISCUSSION

With the facts at hand no real explanation of the phenomena observed is possible, so that any speculations as to possible causes are entirely hypothetical.

The perfect flowered form of *Populus tremuloides* shows irregularities in microsporogenesis and polyspory, both of which phenomena are often associated with hybridity. The homology between the maternal and paternal chromosomes seems to be absolute, as shown by complete and intimate pairing in prepara-

tion for reduction division; which is similar to what Blackburn (2) found in some Salix phen-hybrids between species having the same chromosome number; the first indication of irregularity is the apparent inability of some of the pairs to separate at heterotypic metaphase, an unusual condition. That many of the gametes are not sterile is evident from the fact that much of the pollen germinates and normal embryos are produced by selfing. This hermaphrodite type can hardly have arisen as a cross between two species, in which case the selfed seedlings which are being raised would be expected to show some segregation of forms pointing towards such a cross; as yet they appear quite uniform. This plant should be a good subject for both cytological and genetical studies, but unfortunately it is a tree and the generations are probably at least three to four years, if not longer.

Since the perfect flowered Populus is heterogametic with an XY-sex pair such as is found in the normal male, this seems to be another case in which some factor upsets the internal balance which geneticists claim determines the external mainfestations of sex (9). Intersexes of *Drosophila simulans* reported by Sturtevant (12) possessed two X-chromosomes and were found to be "females, modified by a recessive autosomal mutant gene" that caused them to show male, as well as female, parts. It has never been understood that sex-determination depends merely on the specific sex chromosomes and it is known that dioecious plants can be made to reverse their sex in varying degrees; the best known example of this is described by Schaffner (10) and others in *Cannabis sativa,* in some races of which Hirata (7) has found a heterochromosome sex group in the male.

It is to be regretted that our subject is so ill suited to genetical experimentation.

SUMMARY

1. A specimen of *Populus tremuloides* was found at Ann Arbor, Michigan, apparently normal except that it bore perfect flowers with a small proportion of female and still fewer male flowers.

2. The sex organs are normal in structure and fertile gametes are produced; normal embryos are obtained by artificial selfing.

3. No fertilization resulted from crossing flowers of a dioecious aspen with pollen from the perfect flowers.

4. The haploid chromosome number in the dioecious male form is 19. Reduction is regular and an unequal sex pair is present.

5. The haploid chromosome number in the pollen mother cells and megaspore mother cells of the perfect flowers is 19. Eighteen pairs of autosomes and an unequal sex pair are always found.

6. Irregularities in chromosome distribution occur at heterotypic metaphase; both members of some pairs are occasionally found at one pole. Some chromosomes may fail to be included in the interkinesis nuclei.

7. Interkinesis nuclei show variations in chromosome numbers, some containing as few as 7, others as many as 21 chromosomes.

8. The homeotypic division may proceed normally. In some cells extra spindles are formed and in a few division fails completely and the chromatin runs together in clumps.

9. Polyspory is frequent.

10. Pollen grains show great variation in size. The average size of the grains is larger than in the dioecious male form; some small aborted grains are also present.

11. The sex chromosome group in the hermaphrodite specimen appears to be exactly similar in size and form to that found in the normal dioecious male. The X-chromosome in both is very large and may possibly be compound.

University of Michigan

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EXPLANATION OF PLATES IV–VI

Cytological figures (Figs. 6–20) were drawn with a Zeiss compensating ocular No. 18 and a 2 mm. apochromatic objective, tube length 160 mm., at table level, with the aid of an Abbé camera lucida.

In reproduction all plates were reduced one half.

PLATE IV

FIGS. 1–2. Habit of hermaphrodite flowers

FIG. 3. Longitudinal section of Figures 1–2 (drawn with ocular No. 4 and a 16 mm. objective with the aid of a camera lucida)

FIG. 4. A 2-celled embryo at the micropylar end of an embryo sac (drawn with ocular No. 10 and a 1.9 mm. objective with the aid of a camera lucida)

FIG. 5. Group of young pollen grains before shedding (drawn with ocular No. 12 and a 2 mm. objective with the aid of a camera lucida)

PLATE V

FIG. 6. Heterotypic metaphase plate in dioecious male. Nineteen pairs, sex pair indistinguishable

FIG. 7. Same as Figure 6, but XY-pair evident. Two dark staining-bodies present in cytoplasm at a different level from the chromosomes (B)

FIG. 8. Heterotypic metaphase in dioecious male, profile view. XY-pair on periphery of plate, two dark staining-bodies in cytoplasm

FIG. 9. Heterotypic metaphase in megaspore mother cell of perfect flower. Nineteen pairs of chromosomes including giant and XY-pair

FIG. 10. Nineteen pairs at diakinesis in pollen mother cell of perfect flower

FIG. 11. Heterotypic metaphase plate in PMC of perfect flower. Nineteen pairs

FIG. 12. Same in profile. XY-pair on periphery of plate

FIG. 13. XY-chromosome pair found alone in a cut PMC of perfect flower

FIG. 14. Early heterotypic anaphase in PMC of perfect flower. Part of a spindle showing X- and Y-chromosomes going to opposite poles

FIG. 15. Heterotypic meta-anaphase spindle in PMC of perfect flower. Sex chromosome pair at one pole, autosomes paired at the equator

PLATE VI

All the figures in this plate are from pollen mother cells in perfect flowers.

FIG. 16. Irregular heterotypic meta-anaphase spindle. Giant autosomal pair at one pole, XY-pair at the other, the other chromosomes at the equator in early anaphase. One pair of autosomes not on the spindle

Fig. 17. Late heterotypic anaphase. Sex pair not evident. Lagging chromosomes becoming spun out on the spindle fibres

Fig. 18. Unequal interkinesis nuclei in an uncut cell. Twenty-one or 22 chromosomes and 3 nucleoli in one and 14 chromosomes and one nucleolus in the other nucleus. One chromosome in cytoplasm

Fig. 19. Homeotypic anaphase plates with a dark staining body in the cytoplasm associated with each spindle. Extra spindle with 3 chromosomes dividing

Fig. 20. Chromosomes breaking down at homeotypic anaphase

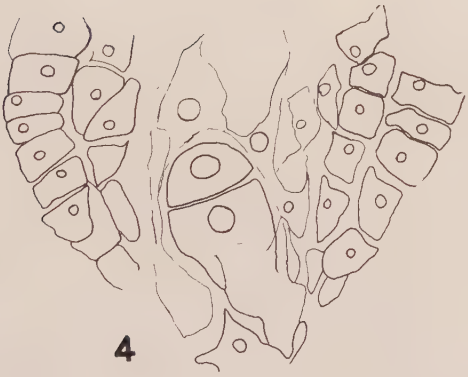
Fig. 21. Five pollen grains within the cell wall of one original PMC. One grain with two nuclei, one with an extra-nuclear nucleolus (drawn with ocular No. 12 and a 2 mm. objective with the aid of a camera lucida)

PLATE IV

1

2

3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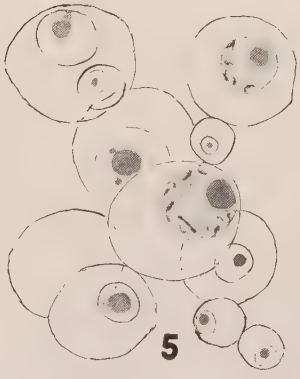
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PLATE V

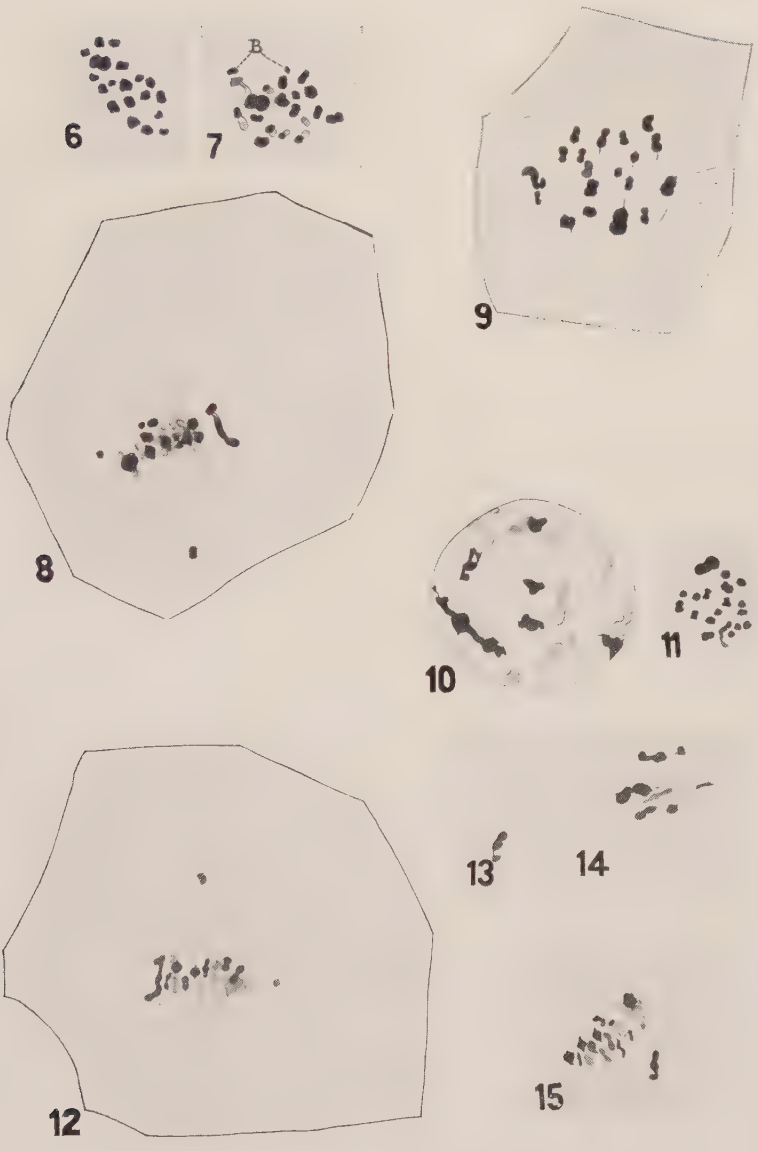
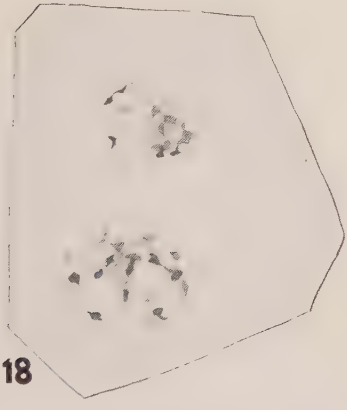


PLATE VI

16

17



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19

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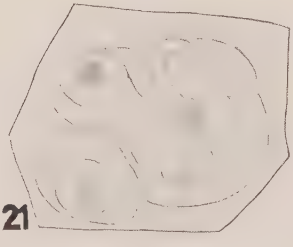

21

ADDITIONS TO AN ANNOTATED LIST OF THE HIGHER PLANTS OF THE REGION OF DOUGLAS LAKE, MICHIGAN*

FRANK C. GATES

Kansas State Agricultural College

AND

JOHN H. EHLERS

University of Michigan

THE material upon which these notes are based are the collections and records of the summers of 1924, 1925 and 1926. During these summers better transportation facilities at the Biological Station have made possible more extended trips and have given the authors opportunity to make a more thorough survey of the remote parts of Emmet and Cheboygan counties.

These records are made in the same general form employed in the authors' previous publication [1] on the species of higher plants of the region about Douglas Lake, comprising Emmet and Cheboygan counties. A revised summary of species by region and counties follows the list. The list is, however, still incomplete. Large areas in both counties have not been visited. Moreover, all collections made thus far have been made during the period from June 10 to August 20. The authors have had no opportunity to observe and collect the early spring and the fall flora, which may be expected to extend the list considerably.

* Contribution No. 233, Department of Botany and Plant Pathology, Kansas State Agricultural College, and Paper No. 265 from the Botanical Department of the University of Michigan.

[1] Gates, Frank C., and Ehlers, J. H. "An Annotated List of the Higher Plants of the Region of Douglas Lake, Michigan," *Papers of the Michigan Academy of Science, Arts and Letters*, 4: 183–284, 1924.

PLANTS FOUND IN THE REGION FOR THE FIRST TIME SINCE THE PREPARATION OF THE PREVIOUS LIST OR OF WHICH THE IDENTIFICATION HAS BEEN MADE SUBSEQUENTLY TO THE PUBLICATION OF THAT LIST

(At the extreme right C = Cheboygan County and E = Emmet County)

Phylum PTERIDOPHYTA

11. Polypodiaceae (Fern Family)

Woodsia obtusa (Spreng.) Torr. C.
Lake bluffs west of Grapevine Point, 1926. (Nichols)

Dryopteris marginalis (L.) A. Gray. (*Aspidium marginale* (L.) Sw.). C.
Cutover beech-maple forest land northwest of Burt Lake, 1925. (Nichols)

Phylum ANTHOPHYTA

9. Potamogetonaceae (Pondweed Family)

Potamogeton strictifolius Benn. C.
Submerged aquatic off Hook Point, Douglas Lake, 1925.

12. Pontederiaceae (Pickerelweed Family)

Pontederia cordata L. E.
Floating patches in colloidal mud at French Farm Lake, 1925.

30. Cyperaceae (Sedge Family)

Rynchospora fusca (L.) Aiton f. E.
Muddy margin of French Farm Lake, 1925.

31. Poaceae (Grass Family)

Panicularia septentrionalis (Hitchc.) Bicknell (*Glyceria septentrionalis* Hitchc.) C.
A single large clump was found near the mouth of Nigger Creek, 1924.

Agropyron caninum (L.) R. & S. C.
Jack pine plains south of Burt Lake, 1924.

Alopecurus aristulatus Michx. (*A. geniculatus aristulatus* Torr.) E. C.
Vestal's Bog, Smith's Bog. Cecil.

35. Iridaceae (Iris Family)

Sisyrinchium montanum Greene. (Included under *S. angustifolium* in B. and B.) E.
Gravelly shore, Big Stone Bay, 1925.

45. Orchidaceae (Orchid Family)

Cypripedium arietinum R. Br. C.
Sandy soil, Pine Point, Douglas Lake.

Lysias Hookeriana (A. Gray) Rydb. (*Habenaria Hookeri* Torr.) E.
Rare, in Thuja bog just west of Cecil, 1926.

85. Oxalidaceae (Wood Sorrel Family)

Oxalis acetosella L. E.
Beech-maple forest at Harbor Point, 1925.

107. Cistaceae (Rockrose Family)

Hudsonia tomentosa Nutt. C.
Jack pine plains west of Black Lake, 1924.

132. Brassicaceae (Mustard Family)

Arabis laevigata (Muhl.) Poir. C.
Herb in aspens west of Bryant's, 1923.

Dentaria diphylla Michx. C.
Low ground in beech-maple forest on Colonial Point, 1926.

140. Salicaceae (Willow Family)

Salix cordata Muhl. C.
Shrub on Grapevine Point, 1923.

157. Ericaceae (Heath Family)

Kalmia angustifolia L. C.
A single clump along a road in Riggsville Bog, 1926.

169. Boraginaceae (Borage Family)

Mertensia paniculata (Ait.) G. Don. E. C.
Three plants on Colonial Point and a single plant in Big Stone Bay, 1926.

171. Solanaceae (Potato Family)

Solanum dulcamara L. E.
Muddy bank of creek from Arnott Lake, 1925.

178. Scrophulariaceae (Figwort Family)

Chaenorrhinum minus (L.) Lange. (*Linaria minor* (L.) Desf.) E.
Railroad ballast along Little Traverse Bay.

191. Lamiaceae (Mint Family)

Stachys arenicola Britton. E.
Herb in sandy thickets at Cecil, 1924.

192. Rosaceae (Rose Family)

Filipendula rubra (Hill) Robinson. E.
Wet meadow near Harbor Point, 1924.

Rubus hispidus L. E. C.
Boggy slashing southeast of Arnott Lake and jack pine plains south of Burt Lake. Cecil.

Rosa palustris Marsh. C.
The plants which occur in the fourth pool at Sedge Point and those at the north end of Smith's Bog have been identified by Eileen W. Erlanson as *Rosa palustris* Marsh.

193. Malaceae (Apple Family)

Amelanchier humilis Wiegand. C.
Jack pine plains south of Burt Lake.

Crataegus succulenta Schrader (*C. macracantha succulenta* (Schrad.) Eggleston.) C.
Small tree along Burt Lake west of Colonial Point, 1923.

Crataegus (nearest *rotundifolia* Moench.) C.
Small tree along shore of Burt Lake, west of Colonial Point, 1923.

194. Prunaceae (Peach Family)

Prunus cuneata Raf. C.
Shrub in jack pine plains south of Burt Lake and west of Black Lake.

199. Fabaceae (Pea Family)

Meibomia grandiflora (Walt.) Kuntze. (*Desmodium grandiflorum* (Walt.) D. C.) C.
Herb in beech-maple forest on Colonial Point, 1924.

Lathyrus pratensis L. C.
Wet places along road at Topinabee, 1925.

203. Crassulaceae (Orpine Family)

Sempervivum tectorum L. C.
Woods east of Lancaster Lake, but undoubtedly escaped from cultivation.

232. Cucurbitaceae (Gourd Family)

Cucumis sativa L. C.
Young plants on sandy shore of Douglas Lake at Hook Point, 1925.

272. Araliaceae (Ginseng Family)

Panax trifolium L. C.
Beech-maple woods at Colonial Point, 1926.

278. Rubiaceae (Madder Family)

Cephalanthus occidentalis L. C.
A few bushes along the shore of Black Lake at the northwest corner, 1924.

Houstonia longifolia Gaertn. C.
Jack pine plains south of Burt Lake.

298. Carduaceae

Carduus crispus L. E.
Roadsides north of Levering, 1925.

300. Lactucaceae

Krigia virginica (L.) Willd. C.
Aspens south of Biological Station, 1926 (Nichols).

Since the publication of the previous list, the species listed below have been found in the second of the two counties of the region and are now recorded from both Emmet and Cheboygan counties, Michigan.

The following entries add Emmet County to the published list:

Phylum LEPIDOPHYTA

1. Lycopodiaceae (Club-moss Family)

Lycopodium tristachyum Pursh. E. C.
Piney woods, Big Stone Bay, 1925.

Phylum ANTHOPHYTA

19. Eriocaulonaceae (Pipewort Family)

Eriocaulon septangulare With. (*E. articulatum* (Huds.) Morong.) E. C.
Penny Lake, Malone Lake, and another small lake north of Carp Lake (Minna E. Jewell).

60. Ranunculaceae (Crowfoot Family)

Ranunculus purshii Richards. E. C.
Muddy banks of Carp River at Cecil, 1924.

Batrachium circinatum (Sibth.) Rchb. (*Ranunculus circinatus* Sibth.) E. C.
Near mouth of Carp Creek at Cecil, 1924.

192. Rosaceae (Rose Family)

Rubus procumbens Muhl. (*R. villosus* Ait.) E. C.
Bog near Big Stone Bay, 1924.

202. Grossulariaceae (Gooseberry Family)

Ribes hirtella (Michx.) Spach. (*R. oxycanthoides calicola* Fernald) E. C.
Stony soil in coniferous woods at Big Stone Bay, 1924

The following add Cheboygan County:

Phylum ANTHOPHYTA

10. Liliaceae (Lily Family)

Anticlea elegans (Pursh) Rydb. (*Zygadenus chloranthus* Richards.) E. C.
Two plants in a Larix bog a mile and a half north of Mud Lake.

30. Cyperaceae (Sedge Family)

Carex albursina Sheldon (*C. laxiflora* var. *latifolia* Boott.) E. C.

Abundant in a restricted area along two trails near the camp on Colonial Point.

31. Poaceae (Grass Family)

Panicularia grandis (S. Wats.) Nash. (*Glyceria grandis* Wats.) E. C.

Banks of Bessey Creek, 1925.

Melica smithii (Porter) Vasey. E. C.

Beech-maple forest near Mud Lake and in a small wood-lot at Riggsville Corners, 1926.

32. Hydrocharitaceae

Philotria canadensis (Michx.) Britton. (*Elodea canadensis* Michx.) E. C.

At least one station in Carp Creek below the Beaver dam, 1925.

35. Iridaceae (Iris Family)

Sisyrinchium (angustifolium ?) E. C.

North of North Fishtail Bay, 1926. (D. Sigler and M. Woollett.)

81. Urticaceae (Nettle Family)

Urtica gracilis Ait. E. C.

Pigeon River east of Wolverine, 1926.

Urticastrum divaricatum (L.) Kuntze. (*Laportea canadensis* (L.) Gaud.) E. C.

Pigeon River east of Wolverine, 1926.

132. Brassicaceae (Mustard Family)

Alyssum alyssoides L. E. C.

Ingleside, 1926.

Arabis lyrata L. E. C.

Two plants found in 1924 in the sand between logs in front of Houghton Hall at the Biological Station where presses are put to dry. Undoubtedly the seeds have fallen from plants which had been obtained in Big Stone Bay where the plant is abundant. Additional stations close to the Biological Station noted in 1925 and 1926.

146. Chenopodiaceae (Goosefoot Family)

Salsola pestifer A. Nelson. (*S. kali tenuifolia* G. F. W. Mey.) Russian thistle. E. C.

A few plants in a farm yard northeast of Burt Lake and two plants along a fence in Hebron.

199. Fabaceae (Pea Family)

Lathyrus maritimus (L.) Bigel. Beach Pea. E. C.

A few plants were transplanted from the Ammophila dune in Big Stone Bay to the open sand at the Biological Station early in August, 1924. Eleven shoots came up in 1925, one of which flowered; by 1926 well established.

281. Valerianaceae (Valerian Family)

Valeriana uliginosa (T. & G.) Rydb. E. C.

A fair sized patch and several smaller patches straggling along the winter road through the long bog north of Hebron.

298. Carduaceae

Cirsium undulatum (Nutt.) Spreng. E. C.

Ruderal near Mud Lake, 1926.

In the list published by the authors in 1924, some of the records for Emmet County were based solely on an unpublished list of Emmet County plants by Fallass and Swift. Such species were indicated by "E*." During the last three summers the presence of the following species in Emmet County has been verified by collections of our own:

30. Cyperaceae (Sedge Family)

Eleocharis acicularis (L.) R. & S. E. C.

Muddy banks of Carp River at Cecil, 1925.

Carex foenea Willd. E. C.

Beech-maple forest west of Pellston, 1926.

31. Poaceae (Grass Family)

Panicum latifolium L. E. C.

Beech-maple forest west of Pellston, 1926.

118. Violaceae (Violet Family)

Viola tricolor L. E. C.

In a beech-maple forest west of Pellston, 1926.

132. Brassicaceae (Mustard Family)

Norta altissima (L.) Britton. (*Sisymbrium altissimum* L.) E. C.
Cecil, 1926.

Cardamine pratensis L. E. C.
Big Stone Bay, 1926.

133. Caryophyllaceae (Pink Family)

Dianthus barbatus L. E. C.
Cemetery and adjacent roadside north of Pellston, 1923.

157. Ericaceae (Heath Family)

Hypopitys lanuginosa (Michx.) Nutt. (*Monotropa hypopitys* L.) E. C.
Piney woods, Big Stone Bay, 1925.

169. Boraginaceae (Borage Family)

Echium vulgare L. E. C.
Railroad ballast at Kegomic, 1925.

199. Fabaceae (Pea Family)

Medicago lupulina L. E. C.
Cultivated and escaped near Levering and on railroad ballast along Little Traverse Bay.

It is interesting to note that two striking representatives of the prairies (*Silphium laciniatum* L. and *S. terebinthinaceum* Jacq.), brought in and maintained for a number of years along Burt Lake, have, since the death of the settler, been driven out in competition with grass and milkweeds. These plants disappeared in 1925.

Revised Summary by Phyla

Phylum	Douglas Lake Region Proper	Emmet County	Cheboygan County	Total in This List
9. Pteridophyta	32	17	32	32
10. Calamophyta	10	10	10	10
11. Lepidophyta	6	7	7	8
13. Strobilophyta	11	12	11	12
14. Anthophyta	891	800	886	1003
Monocotyledoneae	(290)	(258)	(291)	(327)
Dicotyledoneae-Axiflorae	(303)	(277)	(299)	(339)
Dicotyledoneae-Calyciflorae	(298)	(267)	(296)	(337)
Totals	950	846	946	1065

GROWTH STUDIES ON FRUITS

CHEMICAL ANALYSES OF TOMATO FRUITS *

FELIX G. GUSTAFSON

AS FAR as the writer knows, very few chemical analyses have been made of the tomato fruits. In 1875 Dahlen (1) published a paper in which he gave partial analyses of tomato fruits. He used fruits of various ages taken all together, in this way perhaps getting a fair average of the fruits. Stüber (2) using ripe German-grown tomatoes made quite a complete mineral analysis. Albahary (3) made a very incomplete analysis, but he used three different ages of fruits, green fruits without and with seeds and mature fruits. Of all the analytical investigations on the tomato known to the writer, Sando's (4) is the only one in which examinations were made weekly. He began with two-week-old fruits and ended with mature fruits, eight weeks old. MacGillivray (5), using four different ages of fruits, determined the phosphorus content in the pulp, and in the seeds with surrounding pulp. Murneek (6) has also made some analysis of fruits of tomato, together with his analysis of vegetative parts of the tomato plant.

It has been the purpose of this investigation to supplement and extend the work of Sando. Two varieties of fruits were used, the John Baer and Livingston. The plants were grown out of doors in the field and only vigorous and healthy plants were used. A large number of blossoms were tagged at one time and the fruits from these were picked weekly. In this way samples of the same setting were examined at weekly intervals. The fruits thus obtained were studied extensively. The volume, green and dry weight determinations have already been published (7).

* Paper from the Department of Botany of the University of Michigan, No. 264.

One half of each fruit collected was dried, the other half was used in making acidity determinations. Part of the dried material was used to make nitrogen determinations and the rest was used in making ash analyses. The ashing was done in a Hoskins electric furnace, at a cherry red heat in the presence of oxygen.

The amount of crude ash is given in Tables 1 and 2. The percentage of ash is considerably higher in the ovaries than at any other time. From that time there is a gradual decrease in relative amount until the fifth or sixth week, from which time there is a slight increase.

TABLE I

ANALYSES OF THE LIVINGSTON TOMATO *

The one-week sample was very small and the difference between it and the other determinations must not be given too much weight. All analyses were made in duplicates.

Age of fruits	Total green weight per fruit in grams	Dry weight per fruit in grams	Ash in percentage of dry weight	SO_3	P_2O_5	K_2O	CaO	MgO
				In percentage of ash				
At time of blossoming	0.00755	0.0016	9.00					
One week	0.361	0.040	7.68	8.60	14.84	51.50		
Three weeks	32.34	2.03	6.40	5.31	10.50	57.87	2.76	5.16
Four weeks	60.51	3.75	6.10					
Five weeks	98.10	5.64	5.57	5.55	10.52	56.87	3.08	5.45
Six weeks	156.34	8.36	5.52					
Seven weeks (yellowing)	204.90	10.87	6.00	5.40	9.82	56.08	4.00	5.59
Eight weeks (reddening)	252.84	12.32	5.74					
Nine weeks (red)	233.70	10.67	5.83	5.47	10.87	57.26	4.93	5.89

* The ash analyses were made by Mr. Joseph D. Ryan under the direction of Professor Willard of the Chemistry Department and paid for from a grant made to the writer by the Executive Board of the Graduate School.

TABLE II

ANALYSES OF THE JOHN BAER TOMATO

Age of fruits	Total green weight per fruit in grams	Dry weight per fruit in grams	Ash in percentage of dry weight	SO_3	P_2O_5	K_2O	CaO	MgO
				In percentage of ash				
At time of blossoming	0.00604	0.0010	17.45					
One week	0.586	0.05	7.10					
Two weeks	15.761	0.97	7.42	2.77 *	9.68	54.27	2.68	5.30
Three weeks	30.28	1.86	6.66	5.28	9.50	54.54	2.65	5.25
Four weeks	65.79	3.80	6.59					
Five weeks	89.72	4.68	6.52	5.05	8.58	53.70	2.90	5.57
Six weeks (yellowing)	124.30	6.35	6.92					
Seven weeks (yellow-red)	161.61	8.40	6.61	5.18	8.65	53.73	3.34	5.54
Eight weeks (red)	162.00	8.16	7.04	5.23	9.61	53.11	3.30	4.78

* The determination of sulphur was repeated the following year for the two- and three-week samples because in the two-week sample the percentage was so much lower than the others that it was thought best to make certain that this was not an error. The three-week test was also repeated as a check. The data obtained the second year were 5.23 for the two-week sample and 5.16 for the three-week. The first two-week sample was very small and consequently the determination could easily be faulty, while the second year a much larger sample was available.

From the ash, determinations of S, P, K, Ca, and Mg were made. These data are also presented in Tables 1 and 2. In the John Baer the percentage of sulphur, phosphorus and potassium seems to be quite constant. Phosphorus fluctuates slightly, but there is no general loss or gain as the fruits mature, and the potassium decreases from 54 to 53 per cent of total ash. There is an increase of calcium of 23 per cent and a decrease of magnesium of 10 per cent. If the one-week fruit is considered the Livingston shows very decided changes between the first and second weeks. Sulphur decreases from 8.6 to 5.3 per cent and phos-

phorus from 14.8 to 10.5 per cent, while potassium increases from 51.5 to 57.8 per cent; calcium and magnesium were not determined. The material of the one-week-old fruit was rather limited in amount and it is perhaps best to reserve judgment on this point. After the first week there is no appreciable change in the percentage of sulphur, phosphorus and potassium. Calcium increased 44 per cent from the third to the ninth week, and unlike the John Baer the Livingston showed a slight increase in magnesium rather than a loss.

The striking thing about the analyses is the high percentage of potassium and phosphorus. This, however, is usual of fruits and seeds.

The total nitrogen was also determined for the John Baer fruits, and as Table III shows, there was a steady decrease in the nitrogen from the first to the ninth week amounting in the end to 19 per cent. The greatest decrease took place between the first and third weeks. This agrees with Sando's work.

TABLE III

NITROGEN DETERMINATION OF JOHN BAER TOMATO

	Age of fruits in weeks				
	one	three	five	seven	eight
Nitrogen in percentage of dry weight	4.40	3.92	3.62	3.80	3.55

The total nitrogen was determined according to the Gunning method modified by the use of reducing agents so as to reduce any nitrates if present.

Besides these quantitative, qualitative analyses were also made on five-week-old John Baer fruits. The following constituents were found: SO_4, Cl, CO_2, Fe (ferric), Al, Mn, PO_4, Ca, Mg, SiO_2, K and Na.

The H-ion concentration and total titratable acidity were determined in the fresh fruit. Figure 15 gives the result graphically. The young fruit is not very acid, but during the period of rapid growth the H-ion concentration especially increases very markedly and the total acidity also increases though not so much.

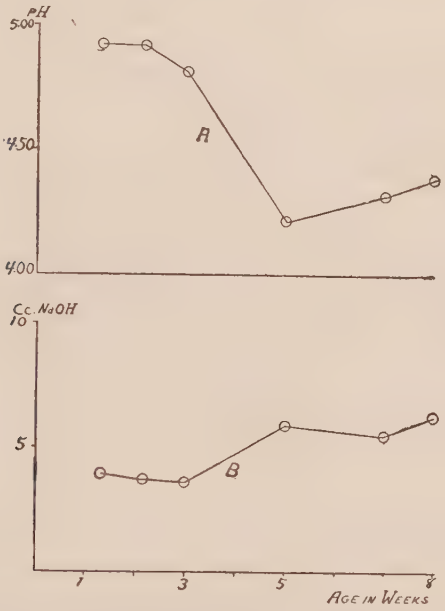

Fig. 15. Hydrogen ion and total acidity concentration changes in the developing tomato fruit. Curve *A* represents the H-ion concentration, *B* the total acidity

During the period of slow growth following, the H-ion concentration decreases slightly but does not approach the early low value. Is there any relation between the rapid growth and the high H-ion concentration? It has been shown by several investigators that acids cause proteins to swell and the suggestion has been made that acid conditions may bring about the increase in size by accelerating imbibition of water. High H-ion concentration and rapid growth are here associated; whether it is the cause of the

rapid growth or the result, is a question which the writer is not ready to answer.

This investigation shows that fruits contain a high percentage of nitrogen, potassium and phosphorous, but that these do not increase in percentage during the development. It is obvious that, though the percentage of these elements does not increase, yet the total amount of each element contained in the fruit increases very much. These elements are supplied to the fruit by and at the expense of the vegetative parts of the plant where they are also needed. Thus there will be a shortage in the leaves, stem and roots, and, as Murneek has pointed out, this undoubtedly is a partial reason for the slowing down of the vegetative growth of a plant when fruits are produced. It seems, however, as if this shortage could be rectified by supplying the plant with an abundance of available compounds in the soil, though of course the absorptive and conductive tissues of the plant may limit the distribution of these elements to the places where needed.

SUMMARY

1. It is shown that the percentage of S, P and K remains nearly constant, after the first week, during the development of the fruits.

2. Calcium increases steadily in the two varieties, while magnesium increases slightly in the Livingston, but not in the John Baer.

3. Nitrogen calculated on the basis of dry weight decreases in the John Baer variety as the fruit develops.

4. In the John Baer the H-ion concentration increases during the period of rapid growth and decreases somewhat during the period of ripening.

5. The titratable acidity shows a more or less steady increase from the first, though the change is not very great.

University of Michigan

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A NEW SPECIES OF THE GENUS PYTHIUM IN THE SUBGENUS APHRAGMIUM *

BESSIE B. KANOUSE AND TRYPHENA HUMPHREY †

ONE of the genera of fungi that has received not a little attention in the past and is still discussed with much enthusiasm is Pythium. In spite of the proposals to unite the genus with Phytophthora, it still seems only logical to follow the conception of the genus Pythium as erected by Pringsheim and later given more definite meaning by Butler (1). Butler keeps as the outstanding characteristic of the genus Pythium the formation of a vesicle in which the zoöspores are finally fashioned. By erecting the two subgenera Aphragmium and Sphaerosporangium he provides for an adequate separation between the fungi having spherical sporangia and those in which hyphae serve as sporangia. In the subgenus Aphragmium he placed five fungi having filamentous sporangia which, he says, are not at all differentiated from the vegetative hyphae of the plants. Edson (3) and Drechsler (2) give excellent accounts of another similar organism, *P. aphanidermatum* (Edson) Fitzpaterick, having a hypha-like sporangium and forming a vesicle but with this difference, viz., one or two definite septa cut off the simple or branched, much swollen hyphae, thus setting apart a definite portion of the plant that then functions as a sporangium. These sporangia may form terminal or lateral vesicles in which the zoöspores are formed and from which they make their escape in the same way as is described by Butler (1) for *P. gracile* Schrenk, and by Ward (5) for *P. debaryanum* Prings.

* Paper from the Department of Botany of the University of Michigan No. 262.

† The single spore isolation and the preliminary study were made by Miss Humphrey.

All these six fungi are known to reproduce sexually with the formation of the usual type of one-spored oögonia accompanied by antheridial organs; some of them may form parthenospores.

During the fall of 1926 a fungus was obtained from a fly dropped into a dish in the laboratory containing *Vaucheria sp.* brought from a ditch near Ann Arbor, Michigan. The organism was isolated and studied from single-spore subcultures.

On sterile flies in conductivity water the organism grows slowly, forming in from six to ten days a halo of fine branching hyphae completely and closely covering the flies. After a month or six weeks the mycelium forms a loose aura one centimeter or less in diameter. In the older cultures as well as in those two weeks old, sporangia and chlamydospores form in abundance; either one or both may be and usually are present in the same cultures.

The fungus grows very rapidly in pea broth made by cooking two dried peas in about 10 cc. of conductivity water for 15 minutes at 15 pounds pressure. In the broth it forms in two days a quantity of sterile mycelium. After seven or more days a dense mat of mycelium covers the liquid in the dish and many loose floccose tufts of mycelium are to be found floating underneath the surface. Neither chlamydospores nor sporangia are formed in this medium throughout a period of several weeks.

When grown in pea broth for from two to six days and then washed three or four times in conductivity water and examined after twenty-four hours, chlamydospores are found in abundance. Small pieces of mycelium left in water in damp chambers for that length of time form a new growth or fringe of richly-branching hyphae extending outward in all directions.

On agars of different sorts at 22° C., the fungus grew well also. Cornmeal, oatmeal and maltose synthetic agars caused a rapid growth. On the corn and oat agars the mycelium made an even flat surface growth, while on other agars it formed overlapping scallops of fan-shaped growths in four days. At the end of a week all the plates were covered with a thick tough felt of hyphae.

Similar reactions were secured when the fungus was grown

at 12° C. on the agars named above, although the growth was remarkably slower.

Well-nourished sterile mycelium that had been grown in pea broth for a few days was thoroughly and carefully washed in sterile conductivity water several times and then transferred to solutions of haemoglobin in percentages varying from 0.05 to 0.003. Only sterile mycelium was found in any of the cultures during the three weeks the experiment was under examination, and little or no new mycelium had been produced.

A very striking feature about the metabolism of this fungus is its ability to use oil. A series of agar plates were prepared in which oil was the sole nutrient used, and the fungus made an exceedingly rapid and luxuriant vegetative growth. Corn oil (Mazola) and pure castor oil were used in percentages of 10, 5, 2.5, 1.25, 0.0625, along with checks of maltose synthetic agar, and also with maltose agar containing 10 per cent corn oil. At the end of only 36 hours the 10 and 5 per cent plates showed mycelial growth reaching a diameter of 6 cm. All the lower percentages of oil showed a growth in surface diameter ranging from 3 cm. to 4 cm. This surpassed the growth on the checks and also on such favorable media as oat and cornmeal agars to a considerable extent. At the end of ten days, the plates were entirely covered with a uniform growth of comparatively straight hyphae forming a tough mat on the surface of the agars. There seemed to be no difference in the results obtained from the use of the two oils. Vegetative mycelium only was produced on all plates and no chlamydospores were formed. This ability to use oil exclusively is indeed an unusual characteristic of the organism.

Sterile radish seedlings having roots about 2 cm. long with abundant root hairs and *Vaucheria gemmatum* were used in infection experiments, but in neither one were there any evidences that the fungus is parasitic even in the slightest degree on these hosts.

The following description of the fungus was drawn from studies of single-spore subcultures grown on sterile house flies in small covered dishes containing about 10 cc. of sterile conductivity water. Cultures grown for seven or ten days at 20° C.

and those grown for four or six weeks at 12° C. gave almost identical reactions for chlamydospore and sporangia formation.

The hyphae are narrow and irregular in width and vary from 2 to 5 μ in diameter (Fig. 1). The walls turn a faint light yellow with chloriodide of zinc in marked contrast to the violet color-reaction obtained with the same reagent used on *Pythiomorpha gonapodioides* Petersen. The protoplasm is coarsely granular and contains vacuoles and numerous refractive bodies other than the oil droplets that are usually found in abundance, especially in the fly and oil-agar cultures. The protoplasm is distributed unequally in the hyphae.

The septation of the hyphae is difficult to observe, since the hyphae are all extremely slender and thin-walled. Septa are rarely seen in the vegetative hyphae, except at the places where chlamydospores occur. It has not been possible to make them out at the bases of the hypha-like zoösporangia, but it is highly probable that they are present since the sporangium becomes empty except for the minute refractive bodies, and remains so. It collapses and becomes so delicate that it is all but invisible at this time; it measures only 1–1.5 μ in diameter. If no basal septum were formed there would be nothing to prevent a refilling of the sporangium with protoplasm streaming into it from the mycelium from which it arises.

The chlamydospores are spherical or elliptical cells varying in size from 9 to 27 μ in diameter; they sometimes assume irregular shapes also (Figs. 4, 6, 7, 8). In the initial stages they are usually if not always formed terminally, but many of them soon become intercalary because of the renewed growth by the formation of hyphae from one or more places (Figs. 4–5). A septum is usually laid down at either side of an intercalary swelling though sometimes one side is in direct communication with the hyphae at the distal end. The septa are usually laid down at a distance of from 10 to 30 μ from the swollen part, and the small portions of the hyphae so included are also filled with dense protoplasm (Figs. 4, 6). When the cell is cut off by two septa the bounding wall is somewhat thicker than it is when a chlamydospore renews growth. The portion of the mycelium

beyond the septum is frequently entirely devoid of protoplasm (Figs. 5, 8). Chlamydospores form in enormous numbers in the fly cultures and in mycelium that has been grown in pea broth and subjected to repeated washings in sterile waters. They are more numerous both before and after zoöspores are in the process of forming. Cultures in which they are abundant one day will sometimes appear to be surprisingly free from them on the following day. These chlamydospores have never been seen to take on the function of zoösporangia, by formation of zoöspores either within them or on short exit swellings such as occur in Saprolegnia. They seem to be accumulations of protoplasm at places in the hyphae that are capable of renewed growth into hyphae or perhaps into the sporangia. In this then they are only partly comparable to the chlamydospores in the Saprolegniaceae.

They do not seem to be the structures that are referred to by Butler as "bud-like" processes in the species of Pythium. The only suggestion of similarity to be found in Butler's entire treatment of Aphragmium is the reference (*l. c.*, Pl. 1, Fig. 1 a), in which he figures a bud-like process of which he says, "there is a resemblance to conidium formation." In the text, however, he makes a definite distinction between the bud-like processes and "gemmae." Of the latter he says, "Gemmae, resembling in their external features those of the Saprolegniaceae are formed in *P. rostratum*. I have not observed them elsewhere, though the vegetative buds mentioned above are probably allied bodies." Similar structures were, however, seen in *P. de Baryanum* by de Bary, and Ward (5) figured them and called them "conidia." Chlamydospores are not reported to occur in *P. aphanidermatum*.

The sporangia are modified portions of the mycelium (Fig. 9), like those described for the subgenus Aphragmium by Butler (*l. c.*). In contradistinction to earlier authors, Butler states clearly, for the species he studied, that the septa found in the hyphae are formed merely in connection with the vegetative condition of the plant, and their appearance near or just below a portion of hypha functioning as a sporangium is merely a coincident, thus making no differentiation whatsoever between the sporangium and the vegetative mycelium. Edson (3) and

Drechsler (2), however, describe for *P. aphanidermatum* one or more septa definitely marking off a much enlarged simple or branched portion which is thus differentiated as a sporangium and from which the vesicle is protruded. The hypha so cut off is called by Edson the "presporangium," and by Drechsler the sporangium. As was stated above, septa are seldom found in this organism, but their presence and relation to that portion of the hyphae that functions as a sporangium seem probable.

In all species of the Aphragmium group, the final fashioning of the zoöspores occurs outside the hypha-like sporangium and within a spherical vesicle (Figs. 10, 17). The boundary of this vesicle is in our new form extremely thin and elastic. It is scarcely visible at times in this organism, and is wholly invisible after the escape of the zoöspores (Figs. 16–17). Yet at the time when the vesicle is visible it is as noticeable as the wall of the hypha-like sporangium from which it arises, the difference being that the vesicle wall quickly and completely disappears while the sporangium wall remains intact, at least for a time after the escape of the zoöspores (Figs. 10, 15). It is plain that the sporangium as a definite organ known in other water-molds is lacking here; it is reduced to a hyphal portion having no visible differentiation from the regular vegetative hypha.

This fungus is clearly not a member of the genus Aphanomyces or any other genus of the Saprolegniaceae with filamentous sporangia, as the zoöspores in such genera are formed within the sporangia.

There is no indication that definite or special hyphae will function as sporangia until the sudden movement of the protoplasm into a rapidly swelling terminal sphere. The sporangium is unbranched, and is relatively long and of practically uniform width (Fig. 9). It is filled with granular protoplasm which passes rapidly into the vesicle. No indication of any stage of spore formation has ever been observed within the sporangium of this fungus. The vesicles vary in size from 12 to 40 μ in width with an average of 25 μ.

The account of the zoöspore formation within the vesicle, the activity of the swimming spores inside the vesicle, their es-

cape and the unusually short time required for the entire process correspond so closely to the accounts given by other authors (1, 2, 5) for members of the subgenus Aphragmium that a repetition of the details is unnecessary. Vacuolization of the protoplasm, cleavage into zoöspores and escape from the vesicle take place in less than thirty minutes. The rocking motion of the protoplasm becomes very rapid during that time, with the result that the zoöspores are finally freed from one another and move rapidly about inside the vesicle with such an impact against the membrane that it is actually seen at times to be stretched. Usually one can only infer that there is a membrane surrounding the spores merely by their rebound from something that is entirely invisible. That there is some resistance offered is further demonstrated by the dumb-bell shape or pinched appearance that the spores have when leaving the vesicle (Fig. 17). The spores usually leave by one exit, but frequently their behavior indicates two or more openings (Fig. 17). At other times a few spores leave by an opening and the remainder swim away in any direction, showing that the vesicle has really disappeared.

The number of zoöspores varies according to the amount of protoplasm contained in the vesicle; there may be from three to twenty-five or more in each vesicle. They measure 8–10 μ. They are biciliate laterally, as is seen by staining with fumes of iodine and are monoplanetic (Fig. 18 d). They are very active and after swimming rapidly about on a slide for from 15 to 30 minutes they come to rest and germinate, often within an hour, by putting out one or more germ tubes.

They usually make their escape singly, but are frequently attached by protoplasmic strands in groups of two or three (Fig. 18 b). They then tumble about end on end for some time and finally become free from one another, or in rare instances fuse into one large zoöspore. When two or more spores are connected, the fine protoplasmic strands can be easily distinguished up to the time of complete separation. The broken strands are quickly drawn into the spores while they are swimming away.

In one instance a large portion of the protoplasm was extruded and it immediately divided into two approximately equal

parts. One of them must have developed cilia, or have had them already formed at this stage, for it swam slowly away as a huge zoöspore. The rest of the bulk of protoplasm was drawn into the vesicle again. The protoplasm at this stage had every appearance of being of a jelly-like consistency.

No sexual reproductive organs have been observed in any of the cultures, though a thorough examination was made of all substrata used, with special reference to the inside of the peas, flies, agars, etc., as it is known that certain of the fungi of the Aphragmium group form oögonia only within the substrata.

The morphological characters of this new fungus seem clearly to place it in the genus Pythium, subgenus Aphragmium of Butler's interpretation, or in the genus Nematosporangium, according to Schröter (4). The hypha-like sporangium with the formation of a vesicle in which the zoöspores are finally fashioned, the presence of modified cellulose in the walls, the laterally biciliate zoöspores and their monoplanetic condition, are all characters which indicate at once a relationship to the other species in this subgenus.

Our fungus differs from the three algal parasitic species described by Butler, *P. gracile* Schrenk, *P. dictyospermum* Raciborski and *P. tenue* Gobi, since it is not known to be parasitic. *P. gracile* Schrenk comes the nearest to answering the description of this fungus, but from Butler's thorough diagnosis of this hitherto complicated species, it seems certain that our fungus is unlike it or any of its three varieties described by him. Butler does not state that he studied *P. gracile* in other than mass cultures; hence it is impossible to determine whether or not he considers it to be homothallic. The evidence is strong in favor of believing our fungus to be heterothallic. Cultures of bacteria-free mass mycelium have been studied under conditions named above for handling the single-spore cultures, but without the production of oögonia or parthenospores. Furthermore, the experiments with haemoglobin, found useful in causing the expression of sexuality in certain of the water molds, all gave negative results. Hence it seems, by inference, more than probable that we are dealing with a heterothallic form. Barring the fact

that *P. gracile* Schrenk may be found to be heterothallic, there is still the marked difference between *P. gracile* and this organism in that the latter forms, under what must be regarded as favorable conditions, an abundance of chlamydospores such as are not reported for *P. gracile* or for any of its varieties.

It differs from the two saprophytic species of Aphragmium, *P. monospermum* Pringsh. and *P. indigoferae* Butler, in having much more delicate hyphae, 5 μ in width as compared with 7 μ and 8 μ given for the two species just mentioned. Oögonia have been found in both species but it is clear that *P. monospermum* is homothallic, as Butler (*l. c.*) states that the antheridia arise "from the oögonial or from distant hyphae." *P. indigoferae* is saprophytic on the waxy covering of the leaves of *Indigofera arrecta* which habitat is quite sufficient, together with the other differences mentioned, to prevent its being confused with our plant. Furthermore, neither of the two saprophytic forms produces chlamydospores. *P. Butleri* Subr., another member of the "gracile group," is also distinguished in part by the fact that it is homothallic and in part by the fact that is is parasitic on tropical plants. There are also morphological differences such as the position of the sporangia and the absence of chlamydospores in *P. Butleri*.

Since this fungus appears to differ from the accounts given for other species of the genus Pythium, it is advisable to consider it a new species of the subgenus Aphragmium, and the name **Pythium afertile,** sp. nov., is proposed for it.

Pythium afertile, sp. nov.

Mycelium 3–5 μ in diameter, branching, non-septate except for septa near the chlamydospores, rare elsewhere, containing minute refractive bodies and oil droplets in the protoplasm, walls thin, coloring a faint yellow with chloriodide of zinc. Chlamydospores profusely formed, spherical, elliptical or less commonly irregular, measuring 9–27 μ when spherical, forming terminally (always ?), becoming intercalary by renewed growth of the hyphae from one or more places, filled with dense coarsely granular

protoplasm, separated from the rest of the vegetative mycelium by one or two septa often laid down at a distance of 10 to 30 μ from the swollen portion, by renewed growth forming hyphae or perhaps sporangia. Sporangia hypha-like, 3–5 μ in diameter, 300 μ or more in length, unbranched, quickly collapsing after the formation of the vesicle, vesicle formed terminally on the hypha-like sporangium, spherical, 9–40 μ in diameter, averaging 25 μ, membrane extremely thin, elastic and hyaline, disappearing at or before the time of the escape of the zoöspores. Zoöspores formed within the vesicle, biciliate laterally, monoplanetic, 8–10 μ in diameter when encysted, kidney-shaped with deep lateral fissure when swimming, 3–30 in each vesicle, germinating by means of one or more germ tubes. Sexual Reproduction unknown.

Collected from *Vaucheria sp.* obtained from a ditch near Ann Arbor, Michigan, October 6, 1926, by Bessie B. Kanouse.

University of Michigan

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DESCRIPTION OF PLATE VII

Fig. 1. Mycelium from a rapidly growing culture showing the characteristic branching

Fig. 2. Swollen tip of a hypha showing the beginning of a chlamydospore

Fig. 3. Later stage in development of a chlamydospore. Mycelium is filled with dense protoplasm; no septum has been formed

Fig. 4. Chlamydospore cut off by septum; growth is being renewed at two places by means of hyphae

Fig. 5. Two intercalary chlamydospores separated by septa from the empty collapsed mycelium

Fig. 6. A mature chlamydospore with septum formed a short distance in the hypha below the spherical portion

Fig. 7. An elliptical chlamydospore showing renewed growth before septa are formed

Fig. 8. An irregularly shaped intercalary chlamydospore

Fig. 9. A long unbranched hypha-like sporangium

Fig. 10. Vesicle formed at the tip of the hypha-like sporangium three minutes later; filled with homogeneous granular protoplasm. Note the collapsed condition of the sporangium in this and in the seven succeeding figures

Fig. 11. Surface vacuoles as they appear in the otherwise homogeneous protoplasm

Fig. 12. A shrinkage of the protoplasm following the disappearance of the small surface vacuoles; a central vacuole is forming. The vesicle membrane can just be distinguished in this and in the three succeeding figures

Fig. 13. The central vacuole increased in size

Fig. 14. The protoplasm contracted into a dense lump at the center of the vesicle following the discharge of the central vacuole at the outer surface of the protoplasm

Fig. 15. Expansion of the protoplasm probably due to the taking on of water by the individual spores which are beginning to be blocked out by cleavage furrows

Fig. 16. Spores separated from one another, or nearly so; vesicle membrane not visible but demonstrated to be present by the rebound of the spores. Cilia can be made out at the surface of the spore ball

Fig. 17. Zoöspores escaping in two places from the vesicle membrane which is so thin at this time that it cannot be distinguished

Fig. 18. Zoöspores outside the vesicle; (*a*) two spores separating after leaving the vesicle: (*b*) spores still attached by delicate protoplasmic strands; (*c*) spores entirely separated as they usually emerge from the vesicle in the shape they assume after swimming for a few minutes; (*d*) spores stained with iodine vapor which reveals two lateral cillia

PLATE VII

CYSTIDIA IN THE GENUS CLAVARIA AND SOME UNDESCRIBED SPECIES*

CALVIN H. KAUFFMAN

THE sudden and recent revival of constructive taxonomic studies in the genus Clavaria has resulted in three publications which have appeared since 1919. First, a careful revision of the species found in Great Britain, entitled *A Revision of the British Clavariae*, by A. D. Cotton and E. M. Wakefield (3). Next came a most useful compilation of the descriptions of all American species, accompanied by a critical study of the type material of each species, — a publication that had long been needed by those mycologists who do their own thinking, for the descriptions of American species had become numerous and were published in widely scattered places. This work was ably done by Dr. E. A. Burt under the title: *The North American Species of Clavaria with Illustrations of the Type Specimens* (1). Finally, in 1923, Professor W. C. Coker published a well-illustrated volume, *The Clavarias of the United States and Canada* (2), which bids fair to open up for good this interesting group of fungi for all American students.

There is still much uncertainty as to the variability of mature spores in any one species of the genus Clavaria. Coker allows much latitude and, as a result, synonyms pile up in his book. Considering that his excellent plates of the spore characteristics are so clear-cut and decisive, one cannot understand the apparent inconsistency in the great variability often shown by the spore measurements given in the text. My own experience, based almost entirely on the examination of fresh plants in good condition, does not bear out the implied conclusion to be derived from

* Paper from the Department of Botany of the University of Michigan No. 261 and from the University Herbarium No. 9.

Coker's records, that the same species may produce spores of markedly different sizes in different individuals of a species.

The trouble appears to be referable to one of two categories: Either two or more different forms are forced into one species, perhaps by including collections which are not normal or not in condition to be identified; or, immature or abnormally large spores are taken into account in making the spore measurements. As I have often pointed out, only mature spores should be measured, and abnormally large spores should not be given undue emphasis within the range of the spore size given. In this genus, to be sure, maturity of spore is not so easily determined because of the hyaline or pale-colored exospore. The spores of a plant that has developed rapidly to full size may, nevertheless, be largely immature. Hence, whether one employs biometrical methods or direct judgments in obtaining the range of spores in a series of mounts, there is likely to be some discrepancy between the results of observers. But after all, caution and experience bring one's results into harmony with those of other careful workers.

But discrepancies also arise from other causes. For example, a type collection may be composite; or both young and mature plants may be present in a type collection. When two observers, as happened with reference to Peck's type of *Clavaria nebulosa*, report decidedly different spore-sizes, something of the sort is likely to be the cause. Dr. Burt records the spore-size of this type collection to be 6–7 × 3–3.5 μ, while Coker gives it as 7.4–11 × 3.6–4 μ. This difference is doubtless accounted for by the presence of specimens or parts of specimens with a young hymenium. Through the kindness of Dr. House, I was able to examine the type specimens of this species also, and found the spores agreed with the measurements given by Coker. Both these observers, however, failed to note that cystidia are present in the hymenium of this plant. This case also illustrates the weakness in the assumption that conclusions drawn from an examination of "types" are infallible as a starting point in its nomenclature. If the type plants and therefore the spores are immature and the measurements become a part of the type description, it may be difficult ever after to know what collections are identical with it.

The occurrence of *cystidia* in the hymenium of any of this group seems to have been overlooked, with perhaps the single exception of *C. pyxidata* Fr. (Coker, p. 92). Such structures usually do not occur in Clavariae. In my studies of this group during the past years, whenever fresh material afforded me the opportunity, I have been able to establish the existence of cystidia in a limited number of species. One of these, *C. nebulosoides* Kauff., has been described in another place (5); while a second one was temporarily referred to *C. fumosa* Fr. (4).

Clavaria purpurea

Specimens from Europe, under the name *C. purpurea* Müll., were distributed by Sydow in Mycotheca germanica, No. 1833.[1] The hymenium of this collection is provided with fairly abundant cylindrical cystidia, which are rounded at the apices, and are hyaline, almost smooth or minutely granulate; they measure about 75–85 × 7–8 μ and project about a quarter of their length above the 4-spored basidia. No record, as far as I can find, is extant concerning their occurrence in this European species. I have a collection from Leal, Colorado, published in a list as *C. fumosa* Fr. (4), which is apparently the same plant, and which also possesses such cystidia. Its spores measure 7–9 (10) × 3.5–4.5 μ. Coker (2, p. 53) notes a collection by Clements now at the New York Botanical Garden, also from Colorado, with spores given as "8–9 × 3 μ"; it is very probable that Clements' plant is just the same as these others, and cystidia should be looked for.

If now Coker's plants from North Carolina have no cystidia and notably longer spores, "8.5–12 × 3.7–4.5 μ," we can assume at least two species confused under this name both in Europe and the United States. The habitat of Sydow's and my own collection is the same, viz. under fir in the mountains. This is also the habitat given by Fries (*Hymen. Europaei*). The species of Coker, with large spores and no cystidia, seems to occur under pines, since both Coker's plants and a collection of Karsten's

[1] A one-half per cent solution of KOH was used with all dried material examined.

from Finland were found under pines. No one can say, of course, whether the species figured in *Flora Danica* had cystidia or not, or what its spore-sizes were.

Assuming that the *C. purpurea* of Coker and the plant of Sweden from Romell which Coker studied, as well as Karsten's plant from Finland, possess no cystidia, what described species is available under which these collections can be placed? The first one that comes to mind is *C. fumosa* (Pers.) Fr. Specimens distributed by Sydow under this name (Mycotheca germanica, No. 454), a copy of which I have examined in our herbarium, and which Coker examined at Kew, seems to be entirely without cystidia in the hymenium. Coker reports the spores of this to be 5.5–8 × 3.4–4 μ, with which the spores of our copy practically agree. My measurements run 6–8 × 3.5–4 μ. But this cannot be Coker's *C. purpurea* of which the spores, according to Coker, measure 8.5–12 μ long.

Could it be *C. nebulosa* Pk.? As I have already stated (p. 142) this species has cystidia and the spores tend to reach the length of Coker's plant. The latter, if it is found to possess cystidia, is therefore very likely *C. nebulosa* which retains its autonomy.

Clavaria purpurea Fr. (Emended)

C. fumosa Kauff. (4, p. 124).

Fructification fleshy, slightly tough when fresh, soon brittle, composed of dense fascicles of simple clubs. Clavulae 5–8 cm. high, 2–5 mm. thick, sometimes forked near the base, without definite stipe, smoky gray with tint of purplish, concolorous within, whitish at base, strict, acuminate upwards but with obtuse apex, usually more narrow at base, hence somewhat elongate-fusiform, subcompressed, often longitudinally furrowed, hollow or the tubule vanishing because of compression.

Microscopic characters: Spores oblong, 7–9 (10) × 3.5–4.5 μ, smooth, hyaline or obscurely tinted by the color of the hymenium. Basidia 4-spored, slender, subclavate. Cystidia rather abundant, cylindrical upwards, narrowed below, hyaline, 75–85 × 5–8 μ. Odor and Taste none.

Growing in abundant, gregarious clusters on the ground in a dense forest of Engelmann spruce and Alpine fir. Collected at Leal, Colorado, August 20, 1917, by C. H. Kauffman.

If the exsicatti and recent accounts of the European *C. fumosa* (Pers.) Fr. are correct, then the Colorado species differs from it by possessing cystidia, by its larger spores, by its colors and by its forest habitat. It differs from *C. nebulosoides* Kauff. (5, p. 118) which also has cystidia in the hymenium, by its stouter habit without a definite stipe, larger spores, color and by its cespitose mode of growth; furthermore in that species the cystidia are lanceolate, each with acute apex. The size to which either may attain is of course not sufficiently known, and further collections may show that the range of the two species is very similar in this regard. This species and *C. fumosoides*, sp. nov., also have much superficial similarity.

Clavaria fumosoides, sp. nov.

Fructification fleshy, very fragile, composed of dense fascicles of simple clubs which are often somewhat joined at base. Clavulae 5–8 cm. high, 2–4 (5) mm. thick, more or less fusiform, i.e. rather regularly narrowed to both ends, gray-lavender, white-mycelioid at base, apex blackened by the sun, not stipitate, minutely pruinose, solid and subconcolorous within, often compressed and furrowed.

Microscopic characters: Spores oblong, 5–6 (7) × 3.5 μ, smooth, hyaline. Basidia elongate, 70–75 × 7–8 μ, 4-spored. Cystidia abundant and crowded in the hymenium, subcylindrical to cylindrical, slightly tapering downwards, rounded-obtuse, hyaline, usually granular within, 110–130 × 5–7 (8) μ, base imbedded in subhymenium. Odor slight, earthy; Taste tardily subnauseous.

Growing in gregarious tufts in an open grassy slope near lake. Type collected at Lake Quiniault, Washington, October 20, 1925, by C. H. Kauffman.

This is close to *C. fumosa* (Pers.) Fr. in spore-size, habit and color as these characters are given by Cotton and Wakefield (3) and by Rea (6). However, the presence of very abun-

dant and prominent cystidia, the long basidia, the solid stem and the taste could hardly have been overlooked by these writers. It differs from *C. purpurea* Fr. by its spore-sizes, solid stem and habitat; also by tints of lavender which are diffused in the otherwise dark gray color. The minute pruinosity is caused by the projecting cystidia.

Clavaria piperata, sp. nov.

Fructification fleshy, slightly toughish, pallid to cinnamon-brown, paler upwards, 4–6 cm. high, from a single stem or slender trunk, which is about 2–3 mm. thick, dichotomously to polychotomously branched; secondary branches pyxidate, at times candelabra-form, curved-spreading at maturity, loosely arranged; primary and secondary branches dilated upwards, with rounded, obtuse sinuses, branching repeated four or five times, terminal branchlets acutely pointed.

Microscopic characters: Spores suboval to subglobose, $4 \times 3\ \mu$, smooth, slightly ochraceous-tinted under the microscope. Basidia elongate, slender, $45 \times 4\ \mu$, 4-spored. Cystidia or cystidia-like conducting organs are present; these project about 12–15 μ above the hymenium, slender, 2–3 (5) μ thick, narrowly lanceolate, subhyaline, extending deeply into the trama. Taste peppery, leaving a distinct burning sensation in back of throat; Odor none.

Growing on conifer logs, gregarious-scattered, in virgin forest of Douglas fir, Western hemlock and spruce. Type collected at Lake Quiniault, Washington. November 2, 1925. Collected by C. H. Kauffman.

This has the growth habit and general appearance of *C. pyxidata* Fr., but differs from the latter by the colored, differently shaped spores, its peppery taste, different color when fresh, and its coniferous substratum. *C. pyxidata* seems to be largely limited to poplar and willow around Ann Arbor. Fries, who collected in a coniferous region, says (*Hymen. Europaei*) "ad ligno putrida. Speciosa in Populo tremula." European notices are scanty with reference to its substratum. Schroeter (7), however, reports it as if on pine alone. Does this mean that

two species occur also in Europe? In all accounts accessible, no mention is made of a peppery or acrid taste in *C. pyxidata* except by Coker (2). An examination of my collections of *C. pyxidata* in the herbarium failed to reveal any cystidia. Here too, Coker seems to report them for the first time. It is entirely probable that the two species occur in the Appalachians, and that some of Coker's plants, those with acrid taste and cystidia, grew on coniferous wood-remains. The spores of the species on poplar are narrow, subfusiform-oblong, hyaline, 4–5 × 2–2.5 μ. The spores of *C. acris* Pk. are echinulate and ochraceous, and the plant has a different growth habit.

Clavaria cystidiophora, sp. nov.

Fructification fleshy, moderately fragile, 10–12 cm. high, inclusive of immersed stem, branched, color varying between "buff yellow" and "warm buff" (R.),[1] apices of the ultimate branches "citron yellow," paler towards the extreme base of stem which is white. Main Stem long, immersed and sometimes tufted at very base, 5–8 cm. long, 10–12 mm. thick just below first branching, tapering downwards, ascending or decumbent; primary branches 5–6 or less in number, elongated, solid, whitish within; secondary branches about 3–4 mm. diam., terete or nearly so, becoming repeatedly short-branched, apices of ultimate branchlets acute or subacute, sinuses of all branching obtusely rounded.

Microscopic characters: Spores oblong, 5.5–7 × 3.5 μ, smooth or obscurely punctate under highest power, tinged ochraceous-buff. Basidia elongate, 75–80 × 5–6 μ, 4-spored; sterigmata slender. Cystidia scattered in hymenium, cylindrical upwards, narrowed below, obtuse, 50–70 × 5–8 μ, variable in length and thickness, collapsing in older plants and then hard to recognize. Odor *of anise,* very noticeable; Taste mild or slight.

Growing in deep banks of humus in virgin forest of Douglas fir, cedar and hemlock, Lake Quiniault, Washington. October 17, 1925. Collected by C. H. Kauffman.

[1] Ridgway's *Color Standards and Nomenclature,* 1912.

The plants have the size, habit and somewhat the color of pale forms of *C. flava* Fr. The species is distinct by its cystidia, spore-characters and odor, and to a less degree by its color and mode of branching. The main stems arise from a common point, so that a larger number of plants form a good-sized tuft.

Clavaria globospora, sp. nov.

Fructification simple, 6–8 cm. high, strict, subcylindrical, terete, even, glabrous, pale "cream buff" upwards, almost "colonial-buff" (R.) downwards, solid, fertile portion 1.5–2 mm. in diameter, sterile stipe portion comprising the lower fourth or fifth, 1–2 mm. in diameter, apex obtuse to subacute, base inserted and naked, without sclerotium.

Microscopic characters: Spores spherical, 5–6 μ, hyaline, smooth. Basidia narrowly clavate, 60–65 $\times$ 4–5 μ, *bi-spored.* Cystidia none. Odor and Taste none.

Scattered-gregarious on very rotten wood of conifers in swampy forest of hemlock, Douglas fir and spruce. Type collected at Lake Quiniault, Washington, October 28, 1925, by C. H. Kauffman.

What generic limits will eventually be given the genera Clavaria, Pistillaris and Typhula, further studies must indicate. At present there is no fixed line between the simple Clavariae and the other two genera. Schroeter's scheme (7, p. 438) of basing the separation on the number of spores to a basidium has fallen down. I have found quite a number of species of Clavaria with 2-spored basidia. The same is true of Agarics. The term "slender" sometimes used to designate a difference between Typhula or Pistillaris and Clavaria is also vague, whether applied to the whole fruit body or only to the stipe. The sclerotium is not used consistently as between Typhula and Pistillaris. The species just described seems to be as good a Clavaria as many others. It differs from *C. appalachiensis* Coker in the fact that the stipe is not yellow and scarcely contrasts in diameter with the fertile portion, nor is it subtomentose at base, but inserted and smooth. The clubs are very nearly cylindrical and

even, not in the least ridged or furrowed; the spores when fresh are truly spherical, and the basidia 2-spored.

Clavaria maricola, sp. nov.

(Maricola — from *mas,* 'male,' and *colo,* 'I inhabit')

Fructification simple, fleshy, erect, surface "light orange-yellow" to "orange-buff" (R.), 7–10 cm. high, slender, 2–6 mm. thick, subequal above the basal portion which tapers downwards (rarely very slightly fusiform), erect, more or less compressed but *solid* and white inside the hymenial layer, sometimes twisted and longitudinally furrowed, glabrous, not conspicuously brittle but becoming soft at base in age.

Microscopic characters: Spores subcylindric, obtuse, hyaline or very slightly tinted with yellowish, 10–14 × 4–5 μ, smooth, minutely granular within. Basidia slender, 108–112 × 4–5 μ, 4-spored, rarely 2 or 3-spored. Cystidia none. Odor and Taste mild.

Gregarious and often abundantly so; occurring on needle beds of Western yellow pine, attached mostly to the male cones, rarely on the needles. Type collected at Takilma, Oregon, in Siskyou National Forest, November–December, 1925. Collected by C. H. Kauffman.

I am well acquainted with *C. ligula* as it occurs in northern Michigan, in the Adirondack Mountains and elsewhere, and this western species is radically distinct by its form, its colors, its habitat and habit, but less so by its spores. By its copiously gregarious mode of growth alone, it departs far from the often solitary or sparse occurrence of *C. fistulosa* and its allies; the latter have hollow stems. Very rarely luxuriant specimens show the ligulate form, but far more often it is subequal in the upper three fourths of its length. In age and especially after rains, the base of the stem becomes very soft, so that all the plants bend over or collapse. When fresh and young it has more of a pale vinaceous-buff color, but at maturity and when dry its colors are as described above. Its selection for the most part of the old fallen male cones is unique.

CLAVARIA SUBBOTRYTIS Coker

FRUCTIFICATION 4–10 cm. high, fleshy, fragile, dichotomously branched, branches arising from a main trunk, color of upper portion intense and beautiful in the fresh growing condition, every portion of the upper two thirds "begonia-rose" to "geranium-pink" (R.), trunk white shading upwards into the bright colors, all parts gradually fading in wind or sun to shades of rose-incarnate or salmon-pink. TRUNK short, 1–3 cm. thick and high, abundantly branched above, whitish or white, concolorous within, unchanged by bruising; main branches generally crowded, 5–10 mm. thick, secondary and apical branches 2–3 (4) mm. thick, slightly divaricate-curved, dilated below the sinuses, longitudinally furrowed or wrinkled, with obtuse sinuses, apical ones with short, obtuse tips, 1–1.5 mm. diam.

Microscopic characters: SPORES cylindrical, 7–9 (10) × 3–3.5 μ, subhyaline with pink tint under the microscope, "pinkish buff" (R.) in mass, smooth, CYSTIDIA none. ODOR and TASTE none.

On the ground, among humus or leaf-mold in forests, especially conifers. Ann Arbor, Michigan, August 2, 1912; Lake Cushman, Washington, October 4, 1915; Takoma Park, Maryland, September 1, 1919; Mt. Hood, Oregon, September 30, 1922; Mt. Gretna, Pennsylvania, September 7, 1924; Lake Quiniault, Washington, October 6, 1925. All collected by C. H. Kauffman.

The description is drawn from plants of my own collections.

This is a relatively rare species but is widely distributed as can be seen from my list of localities. Coker reports it only from North Carolina. The following comments were written before seeing Coker's book, in which there are two good photographs of it.

It must have been seen by others from time to time in this country and was doubtless referred to one of the old species, like *C. formosa* (Pers.) Fr., although it cannot possibly fit the modern European concept of that species. It differs from *C. formosa* in the entire reversal of the color changes during development, and by its smooth and smaller spores. It becomes quite

a different looking plant after full maturity when faded, but a cluster of it in vigorous young growing condition is a most beautiful forest object as seen against mosses and débris where it grows. Although mostly found in conifer or mixed forests, it was found also in an oak woods near Ann Arbor.

The name selected by Coker is unfortunate, because to my mind *C. subbotrytis* does not remind one of similarities with *C. botrytis* Fr. It seems to me quite uncertain whether the plant Coker has called *C. botrytis* can be accepted as that species. In any case, both "*C. rufescens* Schaeff." and *C. botrytis* as conceived by Coker are subject to debatable nomenclatorial questions, entirely apart from their doubtful identification.

University of Michigan

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THE GENUS CLITOCYBE IN THE UNITED STATES, WITH A CRITICAL STUDY OF ALL THE NORTH TEMPERATE SPECIES *

CALVIN H. KAUFFMAN

INTRODUCTION

THE genus Clitocybe comprises so many species, their individual characteristics are often so inadequately given, and the described species so poorly organized in the literature, that there exists an acute feeling of helplessness among students who try to get acquainted with them. It seems that an exhaustive study and review of the mass of forms already described are a pressing need, not only for American students but also as a guide to those European mycologists who more and more compare their forms with ours. Recent papers (17) from abroad indicate that synonymies proposed and opinions expressed concerning American species are too often based on fragmentary information. With a view to ameliorate the situation, an exhaustive synopsis of both European and American species has been prepared for this paper. Under the conditions of the literature existing at present, numerous supposedly new species can be found in almost any locality and thus synonyms will accumulate until the task of organizing such a mass of material will become well-nigh impossible.

Over two hundred and fifty specific names applied to members of the genus Clitocybe, can be found in the literature. The genus is therefore large, even when we subtract synonyms and those species about which present-day mycologists know nothing except the original descriptions. Fries, in *Epicrisis* (7), gives

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descriptions of ninety-nine species, some of which are definitely considered synonyms by modern authors. Meanwhile, in Europe, but especially in the United States, a large number of additional species have been named and described, in America mostly by Peck (23) and Murrill (19).

Identification of collections of Clitocybe is often difficult. My correspondents say they can do nothing with a considerable number of those found in their particular localities. My own experience has been somewhat the same. I shall, therefore, discuss the reasons for the difficulties met in satisfactorily determining a considerable number of the species of this genus, and in this same paper attempt, by an exhaustive synopsis and notes based on critical studies of many fresh collections and of the literature, to smooth over the difficulties of the student working with this genus.

Outside of a relatively small number of species, which have accentuated characters by which they can be easily known, as, for example, *C. illudens*, *C. tabescens* and *C. infundibuliformis*, most of the species fall into groups of closely related members or may look very much alike while differing microscopically. The most painstaking care must, therefore, be exercised in order to obtain all the characters needed for identification.

This involves regard for the hygrophanous character, especially in the smaller forms, and in dry-weather collecting obviously this character cannot be noted. The color of many species is not striking and the different shades of such must be well noted, both in the moist fresh condition as well as after they are faded, or in the case of hygrophanous species, after losing moisture. The lack of such data in descriptions of published species is one of the diffculties encountered by the monographer; in fact some species thus incompletely described will always remain among the doubtful or excluded species. These are characters not retained in a "type collection" and hence a "type" cannot always be a last resort in the critical analysis of a described species. Herbarium collections, to be sure, can be compared, i.e "matched" in this dried condition, but experience with drying over the flame has shown me that rainy-weather

collections and dry-weather collections may have quite different appearances even when properly dried. The effect of the weather on the autumn and pre-winter species is also conducive to a feeling of perplexity even where a species is abundant; collections made from the same place and the same crop may vary considerably in shades of color and moisture markings, especially in case a slight frost has occurred, or with intermittent rains and subsequent winds. Repeated collecting and study of the plants in a local area are, therefore, necessary to disperse such perplexity.

Furthermore, the normal size range of many species of Clitocybe is unusually unstable, so that species whose caps when expanded are generally, say 2–5 cm. broad, not infrequently may show a single plant in the crop with a cap 7 cm. broad. This of course is due to very favorable growth conditions at the time and place. In the following synopsis this characteristic has been taken account of to some extent, although it results in overlapping of contrasting sizes in the key. No other procedure, which has practical value, seemed feasible, and the student must learn by experience that a key is only a guide, and that its use does not lead to a final identification. It is necessary to check one's result by trying the alternate route in the key.

To the ecological influences just discussed must be added the very considerable influence of the habitat. Full consideration has been given in the following synopsis to the "normal" habitat, whether conifer or frondose forest, grassy places, cultivated areas, on needles or in the soil under the needles, on mats of fallen leaves or what not. These conditions are not by any means exclusive, but do play a much greater rôle in the distribution of the species than the amateur realizes. Here again, when the habitat is used to "key out" a species, the result merely indicates that the probability is very great, but does not imply that the species can never thrive under other conditions.

Let me illustrate by a special case which I have lately studied, where the contrast between the Clitocybe flora of a conifer environment and that of the usual frondose woodlots of southern Michigan was brought out in a striking manner. Cer-

tain plantations of the forestry department of the University of Michigan, in what is now called "The Saginaw Forest," were started in 1904. These are now fine young forests of white pine, Douglas fir and Western yellow pine.

The last three autumn seasons were favorable to the development of more or less continuous crops of fruit-bodies belonging to various species of Clitocybe. I made, therefore, during September, October and November of each year, a careful survey of the agaric flora now established under the pines and firs of these plantations. The following species of Clitocybe were found, some of them occurring each year in large quantities, others in quite small or scattered lots:

C. concava Fr.
C. diatreta Fr.
C. diatreta Fr. var. fuscescentipes, var. nov.
C. ericetorum Fr.
C. felleoides, sp. nov.
C. fellea Pk. forma glabreosa, f. nov.
C. Robinsoniae Murr.
C. regularis Pk. var. insistens, var. nov.
C. rivulosa Fr. var. angustifolia, var. nov.
C. sinopicoides Pk.
C. socialis Fr.
C. subconcava Pk.
C. vibecina Fr.

In contrast to the foregoing flora note the list of the more common species of Clitocybe in the neighboring oak, maple, basswood and other woodlots. Here we have:

C. phyllophila Fr.
C. compressipes Pk.
C. angustissima Fr.
C. mortuosa Fr.
C. subhirta Pk.
C. eccentrica Pk.
C. dealbata Fr.
C. odora Fr. var. anisearia Pk.
C. multiceps Pk.
C. illudens Schw.

A number of ubiquitous species, like *C. infundibuliformis* and the species of Laccaria, occur equally in both places.

A notable feature of a considerable number of the species occurring in the pine plantations above referred to is their tendency to appear in circles or arcs. There is practically no other vegetation under the pines; the needle layer is continuous, and the underground mycelium once established grows radially without hindrance except for the trunks of the young pines. As

is well known, such conditions are very favorable for "fairy ring" production by those species which have this tendency. The species under pines which showed this most prominently were *C. diatreta* and its variety, the forms of *C. regularis* and *C. rivulosa* var. *angustifolia*. Scores of "rings" could be seen everywhere, often approaching closely or even overlapping. In the latter case, the circles were broken at region of contact. It would seem that the soil of these pine plantations was already extensively invaded by these and other agarics. The significance of the Agaric flora in these plantations, its source and the mycorrhizal questions involved are matters which have been reserved for future discussion.

To turn again to those characters of the species of Clitocybe which cause confusion, it is clear that the absence of cystidia, and the similarity of spore size of many species, play no small part in many disagreements between modern authors. There are too few microscopic contrasting characters to offset the similarities of the macroscopic characters. No cystidia have been reported for this genus by previous authors so far as I have been able to determine, yet in one collection of my own, described below, viz. *C. vermicularis* var. *cystidiosa*, var. nov., I did establish the presence of typical cystidia. Sterile cells of long cylindric-clavate shape occur on the edge of the gills in *C. decora*; in most others the edge is homomorphous. The spores in this genus have thin walls, but under magnifications of 800 diameters or more, the spore walls of quite a number of species, including the species of Laccaria, are delicately roughened by minute projections. This character is of much importance by virtue of the lack of other microscopical characters and has to be taken into account in any thorough determination of a species.

An additional means of differentiating these ornamentations on the surface of the spore wall of the white-spored Agarics has been demonstrated for some species by Kühner (17), using the iodine reaction introduced by Melzer (18), with Russula spores. This reagent turns the roughened walls of these spores blue. Kühner and others have gone so far as to separate from the genus Clitocybe those species whose spores react in this manner,

transferring them to Melanoleuca and Leucopaxillus, which they consider valid genera.

The basidia are mostly 4-spored in the genus Clitocybe. Those which I have studied in this connection were examined in the fresh condition. Only in *C. atrialba* Murr. collected at Mt. Hood, Oregon, and in *C. maxima* Fr. from Ann Arbor (sense Kauffman, *Agar. Mich.*), were bispored basidia common. In the former, the bispored condition was almost complete; however, an occasional basidium was found with 4 spores. In *C. maxima* both 2-spored and 4-spored basidia were almost equally in evidence. In many of the smaller species the basidia are relatively quite small and the sterigmata not at all prominent, so that great care had to be exercised in the use of only the higher magnification.[1]

The following species were found to be definitely 4-spored in the specimens examined: *C. amara, C. biformis, C. candida, C. cartilaginea, C. conglobata* f. *americana, C. decora, C. diatreta* var. *fuscescentipes, C. ectypoides, C. fragrans, C. illudens, C. phyllophila, C. regularis* f. *annexa, C. socialis, C. suaveolens, C. subhirta, C. tabescens, C. vibecina, C. vermicularis* var. *cystidiosa.*

In most of the species of Clitocybe the lamellae appear to have an exogenous origin, i.e. the pileus primordium is not enveloped in a universal veil. This was shown to be true in *C. adirondackensis* Pk. and *C. cerussata* Fr. by Blizzard (1). Whether this is true of the "squamulosae" section is doubtful, since the presence of minute scales or remnants on the stems of the latter species would indicate a possible endogenous development. Fayod (6), in giving the limiting characters of his tribe "Clitocybés" (including the genera Clitocybe, Lepista, Nyctalis and Laccaria), has expressed himself as follows: "Fruit-body gymnocarp, homomorph [2] or generally heteromorph. Connective tissue slight. Pileus central, differentiating early like the lamellae, but delayed in its development behind that of the stipe

[1] For these and other critical microscopic data reported in this paper, a B. and L. 3 mm. objective with hyperplane No. 15 ocular was used.

[2] The term homomorph means that the edge of the gills lacks specialized "sterile cells" or cystidia or other special differentiation.

during the period of enlargement of the whole." This gives without doubt correctly the course of development and differentiation for all the truly glabrous species of the genus. Blizzard (1) gives nothing to the contrary. Kühner (17), speaking of "*Leucopaxillus paradoxus* (Const. and Duf.) Bours.," which its describers placed in Clitocybe, reports that this species also is decidedly gymnocarp; the development of some other species of Clitocybe, like *C. tabescens, C. sinopica, C. praecox, C. pulcherrima* and others of the "Squamulosae" group, may, however, be angiocarp or hemiangiocarp. The experienced field mycologist, with a good hand lens, need, however, not feel that he will go far astray in his conclusions as to the gymnocarp or angiocarp character of a plant, provided he finds sufficiently young stages of the species of the Agaricaceae collected. In the angiocarp species he can of course not determine the true homologies of such veils as he may observe in this way, and hence the more detailed histological technique becomes a necessity.

The arrangement of the hyphae of the gill-trama was studied by Fayod (6) and has been discussed by me in several papers (11, 12). Fayod recognized four contrasted types of arrangement as follows: (*a*) "trama emmêlée ou irrégulière; (*b*) trama regulière; (*c*) trama bilatérale; (*d*) trama inversée." The English terms are: (*a*) interwoven; (*b*) parallel; (*c*) divergent; (*d*) convergent.

In the genus Clitocybe, as here limited, no species with divergent or convergent gill-trama are admitted. As shown elsewhere (11), species of Armillaria with a divergent gill-trama, and especially when possessed of well-developed veils, do not appear to me to have any close genetic connection with Clitocybe. Generally speaking, one might say that the genus Clitocybe is characterized in this respect by its parallel gill-trama. This, however, is only partly true, as there are a considerable number of species in which we find a more or less distinct interwoven gill-trama. I have taken careful observations on fresh plants whenever opportunity offered and have noted the gill-trama in the following species:

GILL-TRAMA

(*a*) *parallel*	(*b*) *subparallel or subinterwoven*	(*c*) *interwoven*
C. amara	C. biformis	C. adirondackensis
C. atrialba	C. cerussata	C. ectypoides
C. candida	C. compressipes	C. felleoides
C. cartilaginea	C. compressipes f. autumnale	C. illudens
C. concava	C. connata	C. phyllophiloides
C. conglobatum f. americana	C. diatreta var. fusces-centipes	C. Robinsoniae
C. cyathiforme	C. diatreta	C. tabescens
C. decora	C. ericetorum	
C. gallinacea	C. fellea f. glabreosa	
C. morbifera	C. fragrans	
C. multiceps	C. mortuosa	
C. regularis	C. piceina	
C. rivulosa var. angustophylla	C. phyllophila	
C. sinopicoides	C. regularis var. insis-tens	
C. socialis	C. suaveolens	
C. vermicularis var. cystidiosa	C. subconcava	
C. vernicosa	C. subhirta	
	C. tornata	
	C. vibecina	

The interwoven arrangement is present in a greater or lesser degree in different species. This fact and the technical difficulty involved in obtaining a true section parallel with the general direction which the hyphae of the gill-trama take, as well as the fact that in this genus the hyphae of many species are often very small and compactly put together, make the observations tedious and subject to error. In plants in good, fresh condition, however, even when the caps are practically expanded, the trama is usually in a firm position and the hyphae are not loosened and turgid early in development as they are in a number of other genera. By repeated observations on species known to me I found what appeared to be variations from the parallel to the subinterwoven condition in the same species. This led me to use the criterion of branching hyphae as against parallel, non-branching or at least indistinctly branching hyphae, which is necessary as a check against errors due to first impressions. In

the lists given above, the species placed under "parallel" may have a very slight branching, but not enough to destroy the regularity of the parallel-lying hyphae. In the column "subparallel or subinterwoven" we find considerable degrees of branching and interweaving, some approaching a parallel effect, others a truly interwoven mixing whose highest expression is given in column "interwoven."

An examination of these lists shows no important correlation that I have been able as yet to discover between this gill-trama character and the other characters commonly used in separating the genus Clitocybe into sections; nor is any line of relationship with other genera prominently shown by these facts. It can, however, be regarded as a specific character, which in some specimens can be used to distinguish species which look superficially much alike, and when the data are well checked up, will doubtless take its place as a critical specific character.

Another character, well known to students of Clitocybe, is the difference in texture of the gill-trama and the pileus trama of certain species, resulting in a loose connection of the hyphae at the boundary between gills and pileus; hence the gills are said to be "easily separable" from the pileus trama in these species. Fayod (*l. c.*, pp. 384–385) studied the cause of this separability in species of his "tribe Paxillés" and concludes that it is due to the different directions with respect to each other that the hyphae of the pileus and gills take along this boundary.

I have tested this character in numerous species when the plants were in fresh condition, with the following results:

(*a*) *Easily separable*

C. amara
C. atrialba
C. biformis
C. candida
C. cerussata
C. conglobatum forma americanum
C. connata
C. gallinacea
C. maxima
C. multiceps
C. piceina
C. sinopicoides
C. socialis
C. vermicularis var. cystidiosa

(*b*) *Spuriously separable; flesh of pileus scissile, hygrophanous*

C. compressipes and variety
C. cyathiforme
C. diatreta and varieties
C. ditopoda
C. felleoides
C. metachroa
C. mortuosa and variety
C. subconcava
C. vibecina

(*c*) *Not easily separable*

? C. cartilaginea
C. nebularis
C. phyllophilloides
C. regularis and variety
C. tabescens

The technique used in testing the removability of the gills consisted in employing a blunt edge, such as that of a wooden decimeter rule, or the side of a forceps, gently peeling down from the stem end towards the margin of the pileus, or with a gentle scraping effect across the gill-attachments along the pileus. When the plants are water-soaked the result is not certain, as the soft flesh is pushed along with the gills; if the gills are broken near the trama of the pileus by such a sidewise scrape, they leave ridges showing that they are *not* easily separable.

It is to be noted that in the section "Hygrophanae," it is next to impossible to determine this point, since the flesh of the pileus in the species of this group is *scissile*, i.e. peels easily in horizontal layers, so that a thin layer of the pileus is pulled off along with the gills, which may give one the impression that the gills are easily separable. I have called this a "spuriously separable" effect in the lists given above; this is furthermore a test for the hygrophanous character of a species (see Kauffman, 10).

As I have noted elsewhere (15) this character of "lamellis facile secedentibus" was used by Fries (see *Epicrisis*, p. 313) as an outstanding character for his genus Paxillus, with the remark that in this respect the genus Paxillus is "analogous" with the Boleti. Subsequent mycologists have since treated the genus Paxillus as if Fries had used the word "homologous." With the exception of *Phylloporus rhodoxanthus* (Schw.) Bres. (*Gomphidius rhodoxanthus*), which I think properly belongs to the

Boletaceae (see Kauffman, 14), I cannot see why phylogenetic importance should be given to this character in the genus Paxillus as against other characters, in order to connect the Paxilli with the Boletaceae. On the other hand, evidence is certainly accumulating that the strongest connection of certain species of Paxillus is with Clitocybe. In the latter genus we find a considerable number of species which have forked or even anastomosing gills, or which have globose spores, either minutely rough or smooth. The old species of Paxillus have decurrent gills as in Clitocybe. The distinction that remains is the more or less colored epispore in the spores of Paxillus, while in Clitocybe the spores are hyaline. To keep transferring species of Clitocybe to Paxillus, or to erect new genera, is merely evading the problem.

In fact a new genus, Leucopaxillus, described by M. Boursier (2), to which he refers two species also recently described by Constantin and Dufour (4) and collected in the "Fôret de Fontainebleau," is an example of multiplying genera because of the difficulties connected with the heterogeneity of the genus Paxillus. The two species (see p. 159) have hyaline instead of slightly colored spores, indicating Clitocybe, where Constantin and Dufour put them, but in addition these spores are coarsely tuberculate and give a strong blackish-blue reaction to the iodine test. The genus Leucopaxillus is erected on the characteristic connected with this chemical reaction. The spores of the different species of Clitocybe and Paxillus are largely assumed to give no iodine reaction, and this may be true; nevertheless the group of species with spores so reacting need not necessarily be ranked as a genus.

The odor and taste are very useful in distinguishing species, but the variable nature of these characters in the plants or the variable degrees of olfactory sensitiveness in man may and frequently do cause confusion of specific identity.

Two odors occurring in certain species of Clitocybe are rather definite and helpful diagnostic characters. An *anise* odor is present and distinct in *C. odora* and its varieties, in *C. fragrans*, *C. obsoleta*, *C. suaveolens*, *C. subalutacea* and *C. regularis* forma

annexa. The odor of fresh meal, i.e. a farinaceous odor, when strongly present is accompanied by a farinaceous taste; however the chemical changes which occur in the flesh of these plants in age or when continually soaked during rains, or from other influences, often bring about a reduced amount of the substance causing this odor, or a change in taste from that of fresh meal to rancid, bitterish or generally disagreeable. A single collection, therefore, may be misleading. Species of Clitocybe with a distinct farinaceous odor and taste are: *C. albidula, C. aperta, C. brunnescens, C. catina, C. coloradensis, C. ditopoda, C. farinacea, C. fuscipes, C. pinophila, C. praecox, C. sinopicoides, C. sinopica* and *C. squamulosa.*

Other odors given in descriptions should be interpreted cautiously. A number of species, after excluding the foregoing, are said to have "a pleasant odor." This may refer to odors such as are given off by ripe apple or pear fruits, as for example in *C. verrucipes* and *C. griseifolia.* All grades of intensity of bitter, bitterish, disagreeable, nauseous, subnauseous may occur in this genus and these terms have only a very relative meaning as applied to odor and taste. However, in at least one species, viz. *C. gallinacea,* the taste is definitely acrid; in a number of species it is sufficiently bitter to deserve honorable mention, as in *C. amara, C. amarella* and *C. fellea.* An unusual taste, not very strong, is that of *C. socialis,* as interpreted in this paper; tested out on various individuals, it was immediately recognized by most of them as that of castor oil.

Taxonomically, the genus Clitocybe is characterized by hyaline or almost hyaline spores, by the spongy-fleshy to fibrous stem which is continuous with the pileus, by the adnate or decurrent gills, which do not become emarginate or sinuate, and by their generally gymnocarp mode of development.

It can be divided into two subgenera: CLITOCYBE proper and LACCARIA. The subgenus Laccaria is not easily limited and the development of the species not sufficiently studied. Superficially some of the smaller ones look as if they belonged to the genus Lactarius, but the tissue does not contain vesciculose cells, nor milk-bearing lactiferes. They have, however, more or less of

the aspect of rigid Lactarii. The color of the gills varies in the different species from flesh color through amethyst, violet or purple, and they become dusted by the white spores at maturity. The spores are more decidedly echinulate or verrucose than in any of the true clitocybes. As in the latter genus, the gills may be adnate or subdecurrent. The known American species are *C. laccata* and its varieties and forms, such as var. *amethystina* Bolt. var. *striatula* Pk., and var. *pallidifolia* Pk; *C. ochropurpurea* Berk. and *C. tortilis* Fr. These will all be omitted from further discussion in the remainder of this paper.

Without further data on the detailed anatomical structure and on the development of more species it seems premature to attempt an arrangement pretending to show the natural affinities of the species usually placed within the genus Clitocybe proper, or of the genus as a whole or of its parts to other genera. To segregate certain cespitose wood-inhabiting species and establish the separate genus Monadelphus, as was done by Earle (5) and Murrill (19), does not bring together the closely related species. I will content myself, therefore, with an artificial grouping, used at the beginning of the following synopsis, where it serves the immediate purpose of bringing the species of this genus into a comprehensive arrangement in which their identity may be more easily recognized, and thus their further study promoted.

Synopsis of the Species of Clitocybe of the North Temperate Zone

"R." refers to Ridgway's *Color Standards and Nomenclature*, 1912.

The use of a modern author's name after an old author's name indicates that the microscopic facts for the species are taken from the data given by the later author.

General plan of the synopsis: groups I to V

I. Cespitose group 1–16

II. Group in which the flesh turns blackish when broken or bruised 17–26

III. Group in which the surface of the pileus is not glabrous, but provided with innate scales, or floccose, fibrillose or pruinose 27–45

IV. Group with glabrous pileus of rather large size, 5–8 cm. or 6–12 cm. broad..... 47–82

V. Group with glabrous pileus of the smaller sizes, 1–3 cm., 2–5 cm., or 3–6 cm. broad..... 83–154

GROUP I

1. Plants growing in *notable cespitose clusters*, some with tuberous-connate stems; pileus rather large to very large, often difform, *not fibrillose-scaly* but some with diffracted surface in age..... 2
(Sometimes single individuals or a subcespitose condition may occur, but such tendencies are very unusual.)
1. Plants not cespitose, or if so then smaller in size or relatively few in a tuft, i.e. subcespitose (= partly cespitose and partly gregarious)..... 17
2. Plants colored "cadmium-orange" (R.) in all parts, the pileus later becoming "xanthium orange" (R.); gills unequally long-decurrent; pileus 8–20 cm. broad, soon plane or subdepressed, glabrous; stems long, narrowed to base; spores globose, 4–5 μ; odor and taste strong, disagreeable (American).....*C. illudens* Schw.
2. Plants not bright-colored..... 3
3. Pileus 10–20 cm. (or more) broad..... 4
3. Pileus not over 12 cm., usually 4–8 or 5–10 cm. broad, convex-subplane, obtuse; usually numerous in a cluster (Section "Difformes")..... 8
4. Gills not crowded, close or scarcely subdistant; pileus convex-subplane, obtuse..... 5
4. Gills very crowded..... 6
5. Spores ellipsoid, 6–7 × 4–5 μ, smooth, not punctate; gills subdecurrent, running down the stem in long decurrent lines and anastomosing, separable from cap-trama; pileus 5–20 cm., white or creamy-white; whole plant flavescent on drying; stem 5–8 cm. × 10–30 mm., minutely tomentose; odor strong, penetrating; taste bitterish; subcespitose (American).....*C. piceina* Pk.
5. Spores globose, 6–8 μ; gills adnate-decurrent to sinuate, white; pileus mouse-gray to livid, whitish-tan when dry; stem 7.5–10 cm. × 25–40 mm., cespitose; taste pleasant (Syn. of *Trich. molybdinum* Bull., per Ricken) ("good species," v. Höhnel) *C. decastes* Fr.–Rea
6. Pileus at maturity depressed then infundibuliform..... 7
6. Pileus at maturity expanded-plane to wavy-gibbous, 6–12 (20) cm., very fragile, usually white or whitish, sometimes buff or grayish-brown or dingy tan; gills narrow, sinuate to subdecurrent, easily separable from cap-trama, white then *soon dingy-flesh-color;* stem often eccentric, 3–8 cm. × 8–15 mm., white; taste slowly peppery or disagreeable, remaining in the mouth a long time; spores 5–6 × 3–3.5 μ (American and European)
(See *Tricholoma paneolum* var. *cespitosa* Bres.)

7. Margin of expanded pileus sulcate-ridged; pileus white or tinged tan-color; gills subdecurrent, anastomosing on stem, rather broad; stem 2–6 cm. × 20–30 mm., solid, even, glabrous; spores 7–8 × 5–6 μ (Rea), 5 × 3 μ (Kauff.); odor and taste mild (American and European) ..... *C. gigantea* Fr.

7. Margin of the white pileus even; gills subdecurrent, at first rounded behind, not anastomosing, very narrow, white to pallid; stem 5–9 cm. × 20 mm., fibrillose; spores 6–7 × 3–4 μ; taste agreeable; "odor strong, subfarinaceus" — Bres. (American and European) ..... *C. candida* Bres.

8. Spores ellipsoid. (The hygrophanous *C. multiformis* Pk. is given under No. 56 of this Key) 9

8. Spores globose 10

9. Gills crowded to close, narrow, variously attached, plano-adnate, emarginate or decurrent, cinereous-whitish; pileus 5–10 cm., ashy-gray to whitish, margin involute-pubescent; stems cespitose or tuberous-connate, white, glabrescent, solid; spores 6–7 × 2–3 μ (American and European) ..... *C. connata* (Schum.) Bres.

9. *C. coloradensis* Murr. with broad gills and gregarious habit, and *C. elixa* Berk., with distant gills and gregarious habit, may possibly vary into the cespitose habit and will then be sought here. See { 76. *C. coloradensis* Murr. / 69. *C. elixa* Berk.

10. Pileus white or whitish when young or fresh, 4–8 (10) cm. broad... 11

10. Pileus with other colors when young 14

11. Gills crowded, white; spores 4–5 (6) μ in diameter 12

11. Gills close, not crowded 13

12. Margin of pileus thin, slightly striate, at length revolute; gills adnate or slightly decurrent, narrow; stem 5–7 cm. × 6–12 mm., stuffed to hollow; on buried wood (New York) ..... *C. revoluta* Pk.

12. Margin and pileus firm, at length deflexed or inflexed; gills distinctly decurrent, rather broad; stem 9–16 cm. × 10–25 mm., white, solid, minutely tomentulose; odor and taste of *Psalliota campestris* (Washington and California) ..... *C. albiformis* Murr.

13. Growing on logs; gills unequally but truly decurrent, narrow; pileus firm, glabrous, obtuse, white but mottled with darker watery spots; stem 8–10 (15) cm. × 12–20 mm., solid, white, pruinose; spores 3–4 μ — Pk. (New York) ..... *C. marmorea* Pk.

13. Growing mostly in open, grassy places; gills adnate to slightly decurrent or sinuate, medium broad; pileus firm, obtuse, dull white or tinged with grayish, glabrous; stem 5–10 cm. × 6–12 mm., solid, glabrous, white; spores 5–7 (8) μ; taste rather unpleasant (American) ..... *C. multiceps* Pk.

14. Gills remaining white or whitish, or sometimes tinged with gray or straw-yellow in age, crowded 15

14. Gills becoming dingy flesh-colored in age, crowded, unequally subdecurrent; *pileus often eccentric*, gray or grayish-livid (in age dingy-whitish, chamois or pale tan), at length often punctate-granulate; stem 5–10 cm. × 10–15 (20) mm., variable in thick-

ness, solid; spores 5–6 (7) μ (Tricholoma, per Ricken) (European) ..... *C aggregata* Fr.

15. Gills very broad, adnate to slightly decurrent, white; pileus dark isabelline, 10–12 cm., glabrous, obtuse-subdepressed; stem 7–10 cm. × 20–40 mm., *hollow*, glabrous; spores 6–8 μ (Indiana) *C. elephantina* Murr.

15. Gills narrow, crowded; pileus umber to gray or fuliginous at first, fading to tan, sordid whitish, etc., always somewhat changed in color and dingy in age; flesh not thick 16

16. Cuticle of pileus thick and cartilaginous, becoming roughened-granulate-punctate, convex, varying depressed or umbonate-gibbous, 4–6 (9) cm.; gills pallid, *at length straw-color or sordid, tough;* stem subradicate-connate, firmly-stuffed, at length hollow below, brownish or smoky-tinged (especially below), minutely furfuraceous-villose above, 4–8 (10) cm. × 10–15 mm.; spores 6–7 (8) μ (Tricholoma, per Ricken) (American and European) *C. cartilagineum* (Bull. *non* Fr.) Bres.

16. Cuticle not markedly differentiated; pileus 5–10 cm., at length depressed to broadly umbilicate, margin at first involute, white and pruinose, often irregular, wavy or lobed, gills varying rounded-free, emarginate, obtusely adnate or attenuate-subdecurrent; stem-length varying extraordinarily, 10–20 mm. thick, solid, flocculose-pulverulent, often joined at base, tuberous-connate; spores 4–5.5 (6) μ (Syn. = *C. multiforme* Schäff.; *C. pescaprae* Fr.; *C. tumulosa* Fr.; and *C. humosa* Fr., per Ricken) (American and European) ..... *C. conglobatum* Vitt.–Bres.

GROUP II

17. Flesh blackening when broken or bruised. (*Including related species from Tricholoma and Collybia, as placed by some authors.*) Medium to large plants; gills variously attached even in the same specimens or species, varying slightly decurrent, subdecurrent, sinuate, adnexed or at first rounded behind 18

17. Flesh not blackening when broken or bruised 27

18. Spores elliptical in outline (angular in some) 19

18. Spores globose or subglobose (angular in one) 24

19. Pileus hygrophanous, 5–9 (10) cm.; margin pellucid-striate 20

19. Pileus not hygrophanous; stem solid or spongy-stuffed 21

20. Gills subdistant, broad; pileus thin, blackish or fuscous (moist), cinereous or isabelline (dry), obtuse, 2.5–10 cm. broad; stem 5–10 cm. × 6–8 mm., *tough, elastic*, subbulbous, stuffed-hollow, tinged fuscous or cinereous. . . See *Collybia semitalis* Fr. (*non* authors)

20. Gills crowded, narrow; pileus 5–7 cm., campanulate-convex to umbonate-depressed, brown-black (moist), fading; stem 5–9 cm. × 8–15 mm., stuffed, fibrillose, rimose; spores elliptic-fusiform, 8–9 × 4–4.5 μ (Ricken); ovate-elongate 7–8 × 4 μ (Bres.); lanceolate-ovate, 8–9.5 × 4–4.5 μ (Konrad); taste and odor rantid (Ricken) ..... See *Collybia semitalis* authors

21. Spores irregular, subtriangular, subrhomboid or navicular..... 22
21. Spores regular; gills adnexed; odor and taste slightly farinaceous 23
22. Spores triangular, 9–10 × 5–6 μ; pileus umber-nigricans to pitch-black, 3–7 cm., convex then depressed, not fading; stem short, 2–5 cm. × 5–15 mm., mostly tapering down and subcespitose; gills close; taste of ink; in conifer forest (Syn: C. *semitalis* Fr. var. *trigonospora* Bres.) (European)
Clitocybe transformis (Britz.) Maire
22. Spores navicular to subrhomboid, 10-12 × 6–8 μ; pileus 5–7 cm., whitish, fuscescent or with brownish tinge, innately-fibrillose-reticulate; stem concolor, 5–7 cm. × 6-15 mm.; odor and taste slight (*C. ectypa* Fr. var. *infumata* Bres.) (European) (see comments)
Clitocybe infumata (Bres.), comb. nov.
23. Gills narrow, very crowded; pileus 2–6 cm., obtuse, covered with a minute appressed tomentum, whitish to pale grayish-brown; stem 2–6 cm. × 5–10 mm., solid, pruinose at apex; spores subfusiform-elliptic, 5–6.5 × 3 μ; frondose woods
(See *Tricholoma fumescens* Pk.)
23. Gills medium broad, close to subdistant, arid; pileus 3–7 cm., expanded-subdepressed, sooty brown to dark grayish-brown; stem 3–6 cm. × 6–10 mm., spongy-stuffed (solid), innately fibrillose; spores elliptic-fusiform, 7–9 × 4–5 μ; frondose woods
(See *Tricholoma fuligineum* Pk.)
24. Pileus averaging more than 5 cm. broad..... 25
24. Pileus 2.5–5 cm.; taste slightly acid, odor penetrating, very disagreeable; gills crowded and narrow, varying decurrent to slightly decurrent to subsinuate; pileus thick on disk, thin on margin, whitish then smoky-tinged; stem 4–7.5 cm. × 6–12 mm., solid, incrassate or bulbous at base; spores 6–7 × 5–6 μ (New York)..... *Clitocybe subnigricans* Pk.
25. Odor or taste rancid; spores regular; pileus 5–8 (10) cm. broad... 26
25. Odor and taste slight, not farinaceous; spores angular, 6–7 μ in diameter; pileus 9–12 (15) cm. broad, at length deeply depressed and undulate, smoky-gray to olive-gray; gills close, very broad, obtusely adnate; stem 7–9 cm. × 25–55 mm., firm, bulbous; in beech woods
(See *Tricholoma molybdinum* Ricken; (*non* Fries per v. Höhnel.)
26. Gills distant, broad, thick; pileus umbonate, 4–8 cm., lurid ochraceous to fuscous, margin undulate; stem 2.5–5 cm. × 5–15 mm., attenuate to the base, subcartilaginous; spores 5–7 μ in diameter; in conifer forest (Tricholoma, according to Ricken, with pileus 5–10 cm. broad, mottled with watery spots)
Collybia crassifolia Berk.–Bres.
26. Gills close, thickish, rounded behind or truncate-free (broadly adnate per Ricken); pileus 4–6 (8) cm. broad, lurid gray, in age subavellaneous; stem 4–6 (8) cm. × 6–8 (12) mm., stuffed-hollow, subcartilaginous; spores 6–7 μ, smooth, not echinulate (Tricholoma, per Ricken)..... (See *Collybia fumosa* Pers.–Bres.)

GROUP III

27. Pileus dry (or moist), minutely scaly or definitely scaly, or floccose-fibrillose, tomentulose or pruinose-furfuraceous; pileus colored, never truly white or whitish 28
27. Pileus glabrous (dry, moist or hygrophanous) 46
28. Plants not definitely cespitose 29
28. Plants definitely cespitose; pileus 3–7 (10) cm., tomentose then *scaly*, scales tawny-olive to fuscous and often erect; gills decurrent, distant, at first ferruginous then variegate; stems 5–10 cm. × 4–6 mm., slender, equal, at length fuscescent; spores oval subellipsoid, 7–9 × 5–6.5 μ, maturing slowly (Syn. *C. monodelpha* Morg. and *C. ectypa* Fr.) (European and American) *C. tabescens* Scop.–Bres.
29. Plants growing on wood, logs, stumps, etc. 30
29. Plants not on wood 31
30. Pileus convex to plane, obtuse, golden-yellow to yellow with minute blackish scales, 3–8 (12) cm. broad; gills obtusely adnate, crowded, yellow, rather narrow; stem 3–8 (10) cm. × 5–10 (15) mm., yellow, central or eccentric, dotted-scaly; spores 6–7 × 4.5–5.5 μ; on conifer wood (Pleurotus, per Ricken; Tricholoma, per Rea) (European and American) ..... *C. decora* Fr.
30. Pileus umbilicate-infundibuliform, clay-color to dull watery yellow, scaly-punctate, virgate; gills long-decurrent, concolor, narrow, almost subdistant; stem 2–5 cm. × 2–4 mm., solid, paler than cap; spores 8–9 × 4–5 μ (American, throughout the United States) *C. ectypoides* Pk.
31. Plants with pileus rarely reaching 10 or 12 cm., or much smaller 32
31. Plants very large and stout; pileus 10–30 cm., broadly umbonate to plane or subdepressed, silky-tomentose to subscaly, soon ochraceous-tan to rusty-alutaceous; stem clavate-bulbous, 6–12 cm. long, 20–50 (80) mm. thick, silky-tomentulose; spores 7–7.5 (8) × 5–5.5 μ; odor oily-farinaceous (American and European) *C. maxima* Fr.–Kauff.
32. Taste or odor bitter or disagreeable, or farinaceous or nauseous, at least when the flesh is crushed 33
32. Taste and odor none or slight 39
33. Pileus not over 5 cm. broad or averaging smaller; spores ellipsoid, not globose-echinulate 34
33. Pileus 5–8 (12) cm. broad, cinnamon-rufous, silky-subtomentose becoming flocculose-scaly, convex to plano-subdepressed; flesh thick and firm; gills subdecurrent, narrow and crowded; stem 4–8 cm. × 10–15 (20) mm., solid, fibrillose; spores 5–6 × 4 μ, (5–6 × 4–5 μ, subglobose: Kauff.); taste often very bitter (Syn. *C. patuloides* Pk. and *Tricholoma bicolor* Murr.) (European and American) See Plate VIII ..... *C. amara* Fr.–Rick.
34. Taste bitter or nauseous, odor similar 35
34. Taste farinaceous when fresh 36
35. Gills cream-color, close, slightly subdecurrent; pileus dull "coral pink" (R.), subsilky-pulverulent, obtuse; stem tapering down

and subrooting, *connate* below by tomentose-substrigose covering, subcespitose, concolor; spores minute, 4–4.5 × 2.5 μ, oblong; on needles of pine (European and American)..... *C. socialis* Fr.–Kauff.

35. Gills white, subdistant; pileus pale yellowish-brown or pale tawny, 1–2.5 cm., minutely furfuraceous, convex to depressed (or umbilicate); stem 2–5 cm. × 2–4 mm., equal, concolor; spores 6–8 × 4–5 μ:
    (*a*) "Taste bitter; gills adnate or slightly decurrent; stem stuffed (Woods. New York)"..... *C. fellea* Pk.
    (*b*) "Taste nauseous; gills decurrent; stem solid (Grassy ground. Washington)"..... *C. subsocialis* Pk.
36. Gills decurrent, not very distant nor broad; pileus 2–5 cm..... 37
36. Gills adnate, distant, broad, thick, lutescens; pileus 1–2.5 cm., convex-plane, yellowish or brownish-yellow, at length flocculose-scaly; stem 2–3.5 cm. × 3–5 mm., equal or subequal, stuffed-hollow, glabrous; spores 8–9 × 5–6 μ (taste farinaceous to gall-bitter, per Rick.) (European)..... *C. pachyphylla* Fr.–Rick.
37. Gills close or subdistant; spores truly ellipsoid..... 38
37. Gills very crowded, rather narrow, white at length lutescent; pileus 3–5 cm., *brick-red*, plano-depressed or subumbilicate, flocculose-scaly; stem 3–5 cm. × 3–5 mm. (5–10 mm. per Rea), equal, concolor; spores broadly elliptical to subglobose, 8–9 × 6–7 μ (not *C. sinopica* Murrill or Peck) (American and European)..... *C. sinopica* Fr.–Rea
38. Pileus convex-expanded, obtuse, somewhat irregular, flocculose or covered with minute rufous scales; gills close to subdistant, narrowed to both ends, whitish; stem 3–4 cm. × 6–8 mm., solid, minutely scaly-dotted below from cortina, white within; on grassy ground; spores 7–9.5 × 5–6 μ, broadly elliptical, smooth (Michigan)..... *C. praecox* Kauff.
38. Pileus depressed-subumbilicate to cyathiform-subinfundibuliform, minutely flocculose-scaly, incurved margin silky pubescent; gills white or whitish; stem 2–4 (5) cm. × 3–5 (7) mm., subfibrillose, colored like pileus but paler; spores 6–8 × 3–4 μ:
    (*a*) Pileus umber-colored or alutaceous-fuscescent; gills subdistant; stem stuffed, incrassate at base; spores subpyriform, *smooth* (European)..... *C. squamulosa* Pers.–Bres.
    (*b*) Pileus "cinnamon rufous" (R.), "tawny-red or brick-red," depressed-umbilicate; gills medium close; stem spongy-stuffed to hollow, equal or slightly tapering upward; spores elliptical, punctate-rough. Compare with *C. vermicularis*, No 119. (= *C. sinopica* Murr.) (American) *C. sinopicoides* Pk.
39. Spores globose..... 40
39. Spores elliptical or oval..... 42
40. Pileus 3–7 cm broad; spores minutely echinulate..... 41
40. Pileus 1–3 cm , spores smooth, 5–6 μ in diameter, cystidia none; pileus brown with striate margin, then gray, atomate or floccu-

lose, convex-plane; gills gray, long decurrent, narrow, crowded; stem 2–5 cm. × 3–5 mm., fibrous-fleshy, toughish, glabrous (European) ..... *C. parilis* Fr.–Rick. (*non* Kauff.)

41. Pileus incarnate-tawny, umbilicate-plane, covered with concentric red-brown warty scales; gills long-decurrent, crowded; stem 4 cm. × 5–6 mm., equal, concolor, stuffed-hollow; spores 3–4 μ; solitary, among conifers (European) ..... *C. lentiginosa* Fr.–Rick.

41. Pileus citron-yellow to cream-yellowish, convex, subdepressed-umbilicate, silky-tomentulose; gills decurrent, subdistant, narrow, ochraceous-yellow; stem 4–8 cm. × 6–8 mm., subconcolor, equal, stuffed-hollow, fibrillose; spores 4–5.5 μ, mixed woods (American) *C. pulcherrima* Pk.

42. Spores not over 13 μ long 43

42. Spores very large, 15–20 × 8–9 μ, oblong and cylindric, smooth; pileus 2.5–5 cm., reddish-flesh-colored, somewhat scaly-torn; gills adnate or with tooth, at first purplish-violet then brick-red and pruinose, subdistant, thick; stem 2.5–7 cm. × 5–8 mm., deeply radicate (? Belongs to Laccaria) (American) ..... *C. trullisata* Ellis

43. Pileus rather thin, averaging larger than the next; spores not over 8 μ long 44

43. Pileus 3–5 cm. broad, drab; spores 9–12 × 7–8 μ, ovoid; gills short-decurrent, distant, white; stem 6 cm. × 5 mm., equal, twisted, hollow, with tough rind, furfuraceous (probably a Collybia) (Oregon) ..... *C. oculata* Murr.

44. Pileus mostly with yellowish shades, 5–7 cm. broad; stem often eccentric 45

44. Pileus avellaneous to dark fuliginous, 8–12 cm. broad, slightly umbonate becoming infundibuliform, innate-radiate-fibrillose, hispid-fibrillose on disk; gills subdecurrent, narrow, white; stem "with tough rind," 8–10 cm. × 8–10 mm., tapering upwards; spores 7–8 × 5 μ; sometimes cespitose (Washington) *C. avellaneialba* Murr.

45. Growing in conifer forest; pileus umbilicate to subinfundibuliform, alutaceous-ochraceous-yellowish to tile-red, mealy, at length excoriate-scaly; gills irregularly decurrent, subdistant, intervenose-subporose; stem 3–5 cm. × 7–10 mm., concolor, fibrous-corticate, roughish; spores 6–7 × 3–4 μ (European) ..... *C. incilis* Fr.–Rick.

45. Growing in frondose woods; pileus pale yellow or buff, fading, at first hairy-tomentose, glabrescent, convex-plane; gills adnate-subdecurrent, close, whitish or pale yellow; stem 2.5–5 cm. × 6–10 mm., pale, stuffed-hollow, subequal; spores oval-subglobose, 5–6 × 4–5 μ (American) ..... *C. subhirta* Pk.–Kauff.

GROUP IV

46 Pileus not truly viscid (a few subviscid in wet weather) 47

46. Pileus truly viscid; habit of *Collybia semitale* Bres.; pileus obtuse, olive-blackish, shining when dry, submembranous, pellucid-

striate, virgate, 3–5 cm.; gills tinged-grayish, subdistant, obtusely adnate; stem 5–8 cm. × 5 mm., hollow, equal; spores unknown (European) ..... *C. incomta* Fr.

47. Pileus 4–7 (8) or 5–10 (12) cm. broad (frequently in this genus smaller individuals occur along with the larger range) 48
47. Pileus averaging smaller, rarely over 6 cm. broad 83
48. Pileus white or whitish when in the fresh, moist condition, not hygrophanous; spores ellipsoid 49
48. Pileus not white (some whitish when faded and dry) 56
49. Pileus convex to pale or obtuse; flesh rather thick, especially on disk (larger sized plants) 50
49. Pileus becoming plane to umbilicate or depressed, of moderate size, 3–7 cm. broad; flesh thin 55
50. Pileus umbonate 51
50. Pileus not umbonate 52
51. See Fries, *Monogr.*, and No. 54 of synopsis ..... *C. cerussata* Fr.
51. Pileus 5–10 (12) cm. broad, convex, then plane and obtusely umbonate, firm, white or tinged-buff or brownish in age, dry, glabrous; gills adnate-subdecurrent, crowded, 6–7 mm. broad, whitish; stem 5–7 (10) cm. × 10–20 mm., whitish, brunnescent and enlarged downwards, glabrous or slightly floccose-below; odor and taste mild; spores 6–7 × 3–3.5 μ (Ricken), 7–8 × 4–5 μ (Peck) (in Europe and America)
(Syn. *C. cerussata* Ricken, 1914) *C. nobilis* Pk. (1907)
52. Odor and taste mild 53
52. Odor strong, penetrating; smaller and non-cespitose individuals may be sought here (see No. 5 of this Key) ..... *C. piceina* Pk.
53. Gills crowded, narrow; pileus 5–10 cm.; flesh of pileus rather thick and compact; stems 10–20 (25) mm. thick, enlarged below; spores smooth 54
53. Gills close, not crowded, some forked, white; stem 3–8 cm. × 4–8 (10) mm., equal or tapering slightly upwards; pileus 3–8 cm., rather thin and flexible, dry, shining white, unchanging, glabrous, soft to touch; spores 6–7 × 4–5 μ, *echinulate;* in conifer or mixed woods, in arcs (American) ..... *C. albissima* Pk.
54. Pileus satiny-pruinose (at least when fresh or young) as if with a white bloom, pubescent on the involute margin; gills arcuate-subdecurrent, whitish; spores 5–6 (7) × 3–3.5 μ (Kauff.); stem solid or spongy-stuffed, somewhat bulbous, becoming spuriously hollow at times; gills subdecurrent, easily separable from captrama (Europe and United States) (? *C. Overholtzii* Murr.) (Not *C. cerussata* Pk.) ..... *C. cerussata* Fr. (*Monogr.*) (*non* Ricken)
54. Pileus glabrous and naked on the involute margin; spores 7.5 × 4–5 μ; gills decurrent, whitish; stem 2.5–5 cm. long, *solid* (American) ..... *C. robusta* Pk.
55. Gills close to scarcely subdistant, medium broad, adnate-subdecurrent, white becoming dingy yellowish-ochraceous; pileus even, margin silky; stem 5–7 cm. × 4–8 mm., equal, stuffed-hollow,

tough, *solitary* or subcespitose; spores elliptical, 5–7 × 3–4 μ (see comments) (American and European) (not *C. phyllophila* Pk.) *C. phyllophila* Fr.–Kauff. (*non* Ricken)

55. Gills very crowded, 4–6 mm. broad, adnate-subdecurrent, white, unchanging; pileus dead white (moist), shining white (dry), non-hygrophanous, naked, flaccid, repand and substriatulate in age; stem 4–5 cm × 5–8 mm., somewhat hollow, often compressed, equal, white; spores 6–7 × 4 μ (American and European) (*C. subconnexa* Murr.) ..... *C. pithyophila* Fr.–Rea
56. Pileus not olive, green or greenish 57
56. Pileus varying dull green, grayish-green, bluish-green, grayish-olive (at times whitish), convex-plane, even, 4–8 cm.; *odor of anise;* stem 3–7 × 4–8 (12) mm., equal or thickened at base, whitish or green-tinged:
    (*a*) Gills rather broad, subdistant, adnate-subdecurrent, white or tinged greenish; stem stuffed-hollow; spores elliptical, 6–7 × 3–4 μ (Ricken), 8 × 4–4.5 μ (Rea) (European and perhaps American) ..... *C. odora* Fr.
    (*b*) Gills crowded, narrow, pure white; stem solid (European) (= *C. viridis* Fr.) ..... *C. odora* var. *viridis* (Fr.) Kauff.
    (*c*) Gills crowded, narrow, adnate-subdecurrent, *white* or pallid; stem stuffed-hollow; spores elliptical, 6–8 × 4–5 μ (American) ..... *C. odora* var. *anisearia* Pk.
    (*b*) Gills crowded, relatively narrow, some forked or anastomosing, *deep green or deep olive-green;* spores narrowly oblong, 6–8 (–9, –10) × 3–4 μ (American) (See description, p. 196.) ..... *C. odora* var. *pacifica* var. nov.
57. Pileus hygrophanous, 3–8 cm. broad 58
57. Pileus not hygrophanous 59
58. Pileus dark seal brown (moist), fuscous (dry), subumbonate, even; gills very crowded, narrow, subdecurrent, white, forked; stem 8–15 cm. × 10–15 mm., becoming concolor, solid, glabrous, enlarged at base; spores elliptical, smooth, 7.5–9 × 5–6.5 μ; solitary or gregarious (New York) ..... *C. Earlei* Murr.
58. Pileus grayish-whitish or yellowish (moist), fading, convex-plane; gills adnate-subdecurrent, narrow, crowded, whitish; stem 2.5–5 cm. × 4–6 mm., equal, solid (?), white, often compressed; spores 5–6 × 3–4 μ; cespitose to subcespitose (not *A. multiformis* Schaeff.) (American) ..... *C. multiformis* Pk.
59. Pileus thin, at length becoming infundibuliform, usually flaccid; gills soon deeply decurrent (but see also Nos. 66 and 68 and compare *C. gilva* and *C. gilvaoides*) 60
59. Pileus subfleshy to fleshy (rarely thin) 65
60. Spores ellipsoid, smooth 61
60. Spores globose, minutely echinulate; pileus 5–8 cm. broad 63
61. Pileus not umbonate, glabrous and naked 62
61. Pileus umbonate at first, umbo either persisting or disappearing at maturity, with innate silkiness, *rufous-incarnate to pale tan color;* gills white or whitish, close, narrow; stem tapering upward, base

swollen, 4–8 cm. × 4–10 mm., paler than pileus or pallid; spores ovate, 5–8 × 3–4.5 μ (American and European)
C. infundibuliformis Fr.

62. Pileus at length concentrically cracked, sordid pale brownish-tan, fading to sordid whitish, 4–8 cm.; gills very crowded and narrow, whitish or tinged tan; stem equal, whitish; spores 6 × 3–4 μ, pip-shaped; under pines (Fries) (European) ..... *C. senilis* Fr.–Rea

62. Pileus not rimose, 6–10 cm. broad, chocolate-brown to incarnate-brown, pellucid-striate; gills crowded and narrow, dark-colored, cinnamon-brown, etc.; odor and taste almost disagreeable; spores 9–10 × 5–6 μ (European) ..... *C. cacabus* Fr.–Rick.

63. Plants usually densely gregarious; odor and taste somewhat sour or subnauseous 64

63. Plant growing solitary; odor and taste mild; pileus *gilvous-lutescent*, quite thin but not flaccid, *shining;* gills crowded, simple (not forked), white; stem 4–6 cm. × 8–12 mm., concolor, solid, *glabrous;* spores 4–5 μ in diameter (European and perhaps American)
C. splendens Pers.–Rick.

64. In frondose woods; pileus umbilicate from the beginning, at length with broadly recurved and very flaccid margin, *at length tawny-ferruginous;* gills crowded, pallid-sublutescent (not rufous-tawny); stem rather slender, with creeping base, unequal or tapering down, stuffed, tawny; spores 3–4 μ in diameter (European)
C. flaccida Fr.–Rick.

64. In conifer forest; pileus neither at first umbilicate nor umbonate, sometimes with drop-like spots, tawny, becoming brick-reddish or leather-yellowish, margin at length involute; gills crowded and narrow, simple, pallid then tawny-rufous; stem 3–5 cm. × 7–10 mm., unequal, rather stiff, stuffed-hollow, concolor; spores 3–4 μ in diameter (European and American) ..... *C. inversa* Fr.–Rick.

65. Pileus soon cyathiform or subinfundibuliform, but flesh rather thick at least on disk, often abruptly thin on margin, tan-color, reddish-tinted or yellowish-tinted; gills decurrent 66

65. Pileus convex, obtuse or at the most plano-depressed in age; gills adnate-subdecurrent (but see No. 68) 69

66. Spores ellipsoid, ovoid or oval, smooth; margin of pileus at first involute and white-pubescent 67

66. Spores globose, 3–4 μ, *minutely echinulate;* pileus scarcely cyathiform, *yellowish-tan,* mottled with drop-like watery spots, 3–7 (13) cm., margin at length distant-ribbed; gills narrow, *very crowded,* forked, creamy to isabelline-yellow; stem 5–7 cm. × 8–12 mm., stuffed-hollow, paler than pileus; in arcs, conifer forests (European) ..... *C. gilva* Fr.–Rick.

67. Gills at first pallid or buff, soon brownish or ochraceous-rufous, some forked; close or crowded 68

67. Gills whitish or pallid, not changing, subdistant to distant, very venose-connected, of moderate width (4–6 mm.); pileus alutaceous-ochre-yellow to *brick-red, flocculose-silky,* with markedly

crenate margin; stem 3–5 cm. × 7–10 mm., subconcolor, tough, hollow, pruinose, often eccentric; spores oval, 6–7 × 3–4 μ (European) ..... *C. incilis* Fr.–Rick.

68. Spores oval-elliptical, 5–6 × 3–3.5 μ, *smooth;* pileus "rufous" (R.), 4–8 cm. broad; gills *very crowded,* narrow, forked, ochraceous-rufous; stem 3–4 cm. × 3–6 mm., solid (see description, p. 195.) (American) ..... *C. gilvaoides,* sp. nov.

68. Spores oval-subglobose, smooth, 4–5 × 3.5–4 μ (Kauff.), 5–6 × 4–5 μ (Peck.); pileus from pale buff to "*antimony*-yellow" (R.), 3–7 (9) cm. broad, margin persistently incurved, even; gills *close to crowded,* narrow, some forked near stem, pallid, soon "cinnamon buff" or darker; stem 3–6 cm. × 4–8 (12) mm., curved, subrooting from clavate-subbulbous base (New York) *C. biformis* Pk.–Kauff.

69. Pileus umbonate, 4–7 (8) cm. broad 70

69. Pileus not umbonate 72

70. Pileus ashy-gray or fuliginous 71

70. Pileus with color of tanned leather, incarnate tinged, gibbous, very glabrous, even, flesh white; gills *long decurrent,* not forked, narrow, close, whitish to pallid, at length concolor with pileus; stem 2.5–7 cm. long, stout, tapering upwards, solid, subfibrillose, whitish-lutescens; spores in doubt (spores subglobose, 5–7 μ, per Rea) (European and probably American) ..... *C. geotropa* Fr. (*Monogr.*)

71. Gills distant, rather narrow, unequally decurrent, white; pileus fuliginous-fading, delicately virgate; stem 3–5 cm. × 10–12 mm., smoky whitish, firm, subequal, apex velvety; spores elliptical, 7 × 4 μ (Massee) (England) ..... *C. elixa* Berk.

71. Gills crowded, varying rounded-adnate to adnate with tooth or slightly decurrent, easily separable from cap-trama, ashy-whitish; pileus ashy-gray, at length subalutaceous, with involute pubescent margin; stem 4–6 cm. × 8–10 mm., subequal, solid, *fibrillose-tomentose;* spores 8–10 × 3–4 μ, subfusiform (European) *C. inornata* (Fr.) Bres.

72. Stem stout, clavate or bulbous; pileus of these some shade of gray, ashy or grayish-brown. (This is the "*clavipes-nebularis*" group, with apparently a number of varieties and intermediates, including some with equal or subequal or rather slender stems) 73

72. Stem equal or subequal 77

73. Odor distinctly pleasant or fragrant 74

73. Odor none or slight 76

74. Gills rather broad 75

74. Gills narrow, white-subflavescent, close; pileus 5–10 cm., "subviscid when moist" (!), cinereous to mouse-gray, *glabrous;* stem 10–15 cm. × 15–25 (40) mm., solid, glabrous, apex fibrillose-tomentulose, white or tinged concolor; spores ellipsoid, 6–8 × 3–4 μ, smooth; in arcs under Sequoia (California) .... *C. oreades* Murr.

75. Gills crowded, grayish or whitish, short-decurrent; pileus 5–9 cm., "subviscid when moist" (!), glabrous, grayish or avellaneous, slightly deeper colored on disk; stem 6–9 cm. × 10–20 mm.,

stuffed, *glabrous*, white; spores ellipsoid, 5–6 × 3–3.5 μ, smooth; in humus, woods (Washington to California).....*C. griseifolia* Murr.

75. Gills subdistant to almost close, truly decurrent, moderately broad ("narrow" per Ricken, "broad" per Fries), acuminate at ends, white or lutescent; pileus 3–7 cm., very obtuse, *glabrous*, even; stem 2–6 cm. × 6–8 (10) mm., conical or clavate, *subfibrillose*, spongy-stuffed, smoky-livid; spores 6–7 (8) × 4–5 μ (American and European).....(not *C. clavipes* Rick.) *C. clavipes* Fr.–Kauff.
    (*a*) Stem subequal; gills broader and more distant..*C. media* Pk.
    (*b*) Gills forked .....*C. carnosior* Pk.
    (*c*) Plants small.....*C. comitalis* Fr., per Ricken.
    (*d*) Gills distant; pileus pale rosy-isabelline with drab shades; spores 5–7 × 3–4 μ.....*C. subclavipes* Murr.

76. Gills crowded (very crowded, Fr.), equally subdecurrent, whitish or lutescent, narrow; pileus 8–12 (15) cm., *clothed with a nebulous gray pruina when fresh*, fuliginous or fuscous, at length gray; stem 7–12 cm. × 20–30 mm., enlarged below, spongy, stuffed, sordid whitish; spores 9 × 6–7 μ (Bres.); 7–8 × 3–4 μ (Rea); 6–7 × 3–4 μ (Ricken) (American and European).....*C. nebularis* Fr.

76. Gills close to subdistant, short decurrent, narrow, *cinereous;* pileus 8–10 cm., cinereous to mouse-gray, *glabrous;* stem 3–7 cm. × 10–30 mm., pruinose, hollow; spores ellipsoid, 4–6 × 2–3 μ, smooth (California).....*C. Harperi* Murr.

77. Pileus some shade of drab or reddish..... 78

77. Pileus pale shades of yellowish, isabelline or alutaceous (in one specimen almost white)..... 79

78. Pileus large, 10–15 cm., avellaneous, with thick flesh, glabrous; odor and taste *farinaceous*; gills crowded, broad (?), pale pinkish-cinnamon, brownish in age; stem 8–10 cm. × 10–20 mm., subconcolor; spores 6.5–8.5 × 3.5–5 μ (Colorado) .....*C. coloradensis* Murr.

78. Pileus 5–7 cm., brick-red; *spores globose, large, 10–12 μ diam.;* gills subdistant, decurrent, narrowed to each end, white, subvenose; stem 5–6.5 cm. × 15–20 mm., solid, under oaks (California) *C. sphaerospora* Pk.

79. Pileus not white..... 80

79. Pileus white, fuscescent on centre, 5–10 cm., at length depressed (sometimes subinfundibuliform), silky; gills crowded, pure white, adnate to sinuate-uncinate; stem 5–8 cm. × 6–10 mm., incrassate at base, *covered elegantly with black floccose squamules;* spores elliptic, 8 × 5 μ; odor fragrant (Syn. *C. puellula* Karst.) (European) .....*C. verrucipes* (Fr.) Maire

80. Gills adnate or slightly decurrent, close to crowded..... 81

80. Gills decurrent to long decurrent, narrow, very crowded, forked, creamy-pallid then isabelline-yellow; pileus 3–7 (13) cm., *isabelline-yellow*, often watery spotted, the involute pubescent margin at length distant-ribbed; flesh subconcolor, stem 5–7 cm. × 8–12 mm., stuffed-hollow; spores globose, 3–4 μ, minutely echinulate (European).....*C. gilva* Fr.–Rick.

81. Pileus glabrous and naked..... 82

81. (*a*) Pileus covered by a very thin superficial silky villosity, alutaceous, fading to pallid or whitish, not hygrophanous, 5–10 cm.; plant *tough*, subcespitose; gills close, whitish or tint of cap-color; stem *elastic*, 5–7 cm., straight or decumbent, whitish; spores unknown; in beech woods (European and American) *C. phyllophila* Fr. (*Monogr.*)

(*b*) Pileus 3–8 cm., vinaceous-buff, otherwise the same; spores oval-globose, 4–5 × 3.5–4 μ. (See No. 145 *e*)

82. Gills white, rather broad, intervenose; pileus 5–10 cm., yellowish-flesh color or pale yellow, with thick flesh, obtuse; stem 4–7 cm. × 10–20 mm., white or discolored, glabrous; spores 7–8 × 3–4 μ; odor and taste very pleasant (Tricholoma, per Rea) (European) *C. opipara* Fr.–Rea

82. Gills dull rosy-isabelline, narrow; pileus 6 cm., pale isabelline, margin sublobed, stem 2.5 cm. × 6 mm., slender, solid, concolor; spores 7–8 × 4–5 μ; between railway ties (Oregon)... *C. vialis* Murr.

GROUP V

83. Pileus white, whitish, watery-white, creamy-white or straw color when moist 84

83. Pileus not whitish (except by considerable fading); species with *pale* shades of flesh-color or drab, of brown, of tan, isabelline, of gray or of other colors, are to be looked for here 111

84. Gills subdistant 85

84. Gills close to crowded 89

85. Pileus umbilicate 86

85. Pileus more or less umbonate or gibbous or turbinate 87

86. Stem white or whitish 2–3 cm. × 2–5 mm., pubescent, sometimes compressed, stuffed-hollow; pileus *1–3 cm.* broad, white, lutescent; gills more or less decurrent, whitish; spores ovoid, 4–5 × 2.5–3 μ, very minutely echinulate; odor and taste slight; margin of woods and in fields (somewhat glassy in appearance, like an Hygrophorus) (European and American) ..... *C. ericetorum* Fr.–Bres.

86. Stem fuscous (moist), paler (dry), hollow, glabrous, equal, 2–3 cm., slender; pileus *0.8–1.5 cm.*, whitish (moist), pure white (dry); gills adnate or slightly decurrent; spores *globose*, 5–6 μ; odor and taste *farinaceous;* under pine (New York) ..... *C. fuscipes* Pk.

87. Stem solid, 3–5 cm. × 4–8 mm. 88

87. Stem hollow, equal, 3–4 cm. × 2–3 mm.; pileus 2.5 cm., avellaneous on the small umbo; gills rather broad, discolored on drying; spores 5–6 × 2.5–3.5 μ; in woods (Washington) .. (*C. subfumosipes* Murr.

88. Spores subglobose, 5–6 × 4–5 μ; gills at first adnate becoming decurrent, forked, intervenose, white; pileus 2.5–3.5 cm., at first conical to subturbinate then plane, the involute margin tomentose; stem equal or subbulbous, white; conifer woods. (There is also a var. *monstrosa* Pk. with reticulate-porous gills.) (New York) ..... *C. subsimilis* Pk.

88. Spores ellipsoid, 6–7 × 3–4 μ, smooth; gills decurrent, rather narrow, white; pileus 5–6 cm., convex to plane, usually gibbous; in woods (Washington) ..... *C. washingtonensis* Murr.
89. Growing on logs; stem slender; spores globose or subglobose 90
89. Growing on the ground or humus 91
90. Pileus hygrophanous, creamy-white (moist), whitish (dry), plane to infundibuliform, *umbilicate*, 3–5 cm.; gills crowded, narrow, forked, decurrent; stem equal, 4–6 cm. × 2–4 mm., stuffed, whitish; spores 4 × 3 μ (New York) ..... *C. leptoloma* Pk.
90. Pileus dry, white, expanded-subplane, 1.5–3.5 cm.; gills crowded, narrow, adnate or slightly subdecurrent, white; stem 2.5 cm. × 2 mm., stuffed-hollow; equal, whitish; spores 4–5 × 3–4 μ (New York) ..... *C. truncicola* (Pk.) Sacc.
91. Odor distinguishing, farinaceous or anise; spores ellipsoid or ovoid (see also 95 *a*) 92
91. Odor none or slight 97
92. Odor of anise. (Cf. also No. 56 and No. 101 of synopsis) 93
92. Odor and taste farinaceous when plant is in fresh condition 94
93. Pileus umbilicate, watery whitish (moist), hygrophanous, umbilicus darker (moist), pure white (dry), 2–3 cm.; gills adnate-subdecurrent, close, cream color; stem 4–6 × 3–5 cm., pallid, stuffed-hollow; conifer forest; spores 6–7 × 3–4 μ (Ricken) (American and European) ..... *C. sauveolens* Fr. (*Monogr.*)
93. Pileus not umbilicate, watery-whitish (moist), whitish (dry), 2–5 cm.; gills adnate to subdecurrent, close, medium broad; stem 5–7 cm. × 4–6 mm., whitish or sublutescent, equal, elastic; in frondose woods; spores 6–7 × 3–4 μ (American and European) *C. fragrans* Fr.–Rick.
94. Gills at maturity decurrent to long-decurrent; in conifer or mixed forests 95
94. Gills adnate or slightly decurrent 96
95. Pileus plane, then cyathiform-subinfundibuliform, whitish (slightly tinted in wet weather), margin even, 3–5 cm.; gills crowded, narrow, whitish; stem equal, 3–5 cm. × 3–5 mm. stuffed-hollow, tough, whitish; spores ovoid, 4–5.5 × 3 μ; in frondose or mixed woods (American and European) ..... *C. catina* F.
95. Pileus umbilicate, pure white, satiny, subviscid in wet weather, striate on margin, 2–4 cm.; gills *very crowded*, medium broad, whitish; stem 3–5 cm. × 4–6 mm., *very tough*, equal, stuffed-hollow; spores 4–5 × 2–3 μ; in conifer forest (odor not strong) (American and European) ..... *C. tuba* Fr.–Rick.
96. Growing in conifer woods; pileus 1–3 cm., convex then umbilicate, watery-whitish (sometimes tinged brown: see forma *centralis* Pk. No. 161 a), striatulate (moist), hygrophanous, whitish (dry); gills close, whitish; stem, stuffed-hollow, 2–4 cm. × 2–4 mm.; spores 5–6 × 2.5–3 μ (American) ..... *C. albidula* Pk.
96. Growing in grassy places, roadsides, etc.; pileus 2–3 (5) cm., satiny-shining, whitish, companulate-convex, often difform (= var. *deformata* Pk.); gills adnate, horizontal, crowded, pallid:

(*a*) Stem 4–5 cm. × 4–7 mm., stuffed, fibrous-fleshy, white; spores 5–6 × 3–4 μ (European and American) *C. dealbata* Fr.–Rick.

(*b*) Stem 2.5–5 cm. × 2 mm., slender, solid; pileus sometimes tinged lilac and with zones; spores 4 × 3 μ (Peck), 4–6 × 2–3 μ (Murrill) (American) ..... *C. aperta* (Pk.) Sacc.

97. Taste not acrid. (*C. phyllophiloides* is sometimes slightly acrid; see No. 107) 98

97. Taste acrid; odor earthy-spicy; pileus convex then cyathiform, whitish to "pale pinkish buff" (R.), *hoary-satiny*, 2–5 (6) cm.; gills subdecurrent, close to crowded, narrow, *pale pinkish buff;* stem 4–6 cm. × 3–6 mm., concolor, firmly stuffed, at length hollow; spores short-elliptical, minute, 4 × 2–3 μ; in conifer or mixed forests (American and European) ..... *C. gallinacea* Fr.–Kauff.

98. Pileus white or whitish or at most "pale pinkish buff" (R.) 99

98. Pileus straw-color or yellowish, hygrophanous, gills subdecurrent to decurrent; stem pale yellowish, hollow, glabrous, equal or subequal:

(*a*) pileus 2–4 cm.; gills narrow, of medium distance; spores 5–7 × 3–4 μ; under redwood (California) .. *C. subdicolor* Murr.

(*b*) pileus reaching 6 cm.; gills crowded; spores 6–7 × 3–4 μ; in woods (Washington) ..... *C. subcandicans* Murr.

99. Pileus with a satiny-hoary, whitish more or less shining surface, as if with a bloom 100

99. Pileus naked without such a surface hoariness 102

100. Pileus not umbonate (*C. compressipes* Pk. forma *autumnale*, f. nov., may be sought here; see No. 104) 101

100. Pileus at length depressed-umbonate, very regular, white, 2–5 cm., becoming delicately *rimulose-rivulose;* gills adnate with tooth, very crowded, narrow; stem 2–3.5 cm. × 3–4 mm., fibrous, tough, equal or attenuate downwards, unpolished, whitish; spores 4–5 × 2–3 μ (Ricken); 4–6 × 3–4 μ (Rea); in frondose or mixed woods (rare) (Europe and United States) *C. tornata* Fr. *Monogr.*)

101. Pileus 1–3 cm., whitish then shining white, even; *stem cartilaginous becoming soft*, equal, 2–5 cm. × 2–4 mm., somewhat radicating at villose base; gills crowded, narrow, adnate-subdecurrent; spores 4–5 × 2–3 μ (Ricken) (European and American):

(*a*) In frondose woods; pileus umbilicate ... *C. candicans* Fr.–Rea

(*b*) In conifer (fir) woods; pileus not umbilicate *C. candicans* Fr. (*Monogr.*)

101. Pileus 2–5 cm., watery white (moist), whitish (dry), very regular, convex-plane, even; stem tough, solid or persistently spongy within, base enlarged by mycelioid-tomentum intergrown with needles, 3–5 cm. × 4–6 (7) mm. above base; gills acuminate-subdecurrent, narrow, crowded, *pallid;* spores oval, 4–5 × 3 μ; *under conifers;* odor of anise (See full description, p. 197.) (American) ..... *C. regularis* Pk. (Emended)

102. Pileus hygrophanous, 2–5 (6) cm. broad 103
102. Pileus not hygrophanous, sometimes appearing to be so in wet weather 105
103. Stem glabrous except the pubescent or hairy base, often irregularly curved or flexuous 104
103. Stem fibrillose-reticulate, base with mycelioid-tomentum, whitish, equal, stuffed-hollow, 2.5–4.5 cm. × 4–8 mm.; gills whitish, close, narrow, adnate-subdecurrent; pileus watery white and striatulate (moist), whitish (dry), convex-plane to depressed; spores 6–8 × 4–5 μ; in frondose woods (New York)
C. subcyathiformis Pk.
104. Stem slender, 2–3 mm. thick, 3–5 (7) cm. long, *white*, stuffed; gills *very crowded* and narrow, subdecurrent, white; pileus plane-depressed, not umbilicate, watery white (moist), pure white (dry); spores 3–4 × 2–3 μ (Ricken); in frondose woods (Cf. *C. phyllophiloides* Pk.) (American and European)
C. angustissima Fr.
104. Stem 3–6 (7) mm. thick, 2–4 cm. long, hollow, usually compressed, whitish, *becoming tinged with "ochraceous-buff"* (R.), sometimes hoary-silky; gills *close*, rather narrow, whitish with creamy tint; pileus watery-whitish (moist), dull dingy white (dry), even; spores elliptic-ovate 4.5–5.5 × 3–3.5 μ, smooth; frondose woods; fading to dull white in the herbarium after it is dried (American) ..... *C. compressipes* Pk. forma *autumnalis*, f. nov.
105. Pileus 2–5 cm. broad 106
105. Pileus 1–3 cm. broad 109
106. Stem slender, 2–4 mm. thick; pileus umbilicate, or subinfundibuliform 107
106. Stem 5–8 mm. thick, tapering upward, hollow, white; pileus plane to depressed, white, up to 6 cm. broad; gills decurrent, rather narrow:
(*a*) In grassy places; gills very crowded; spores ellipsoid, 5 × 3 μ (Minnesota) ..... *C. Whetstoneae* Murr.
(*b*) In fir forests; gills more or less crowded; spores ovoid, 6 × 4 μ (Oregon) ..... *C. variabilis* Murr.
107. In frondose and mixed woods; stem stuffed-hollow, equal 108
107. In conifer woods, among needles or moss; stem solid, equal, 2.5–4 cm. long, white; pileus 2.5–6 cm., whitish or tinted "light ochraceous buff" or yellowish on centre, at length depressed-subumbilicate; gills narrow, close, white to pallid, adnate-subdecurrent; taste subfarinaceous or slightly acrid; spores 4–5 × 2–3 μ (Cf. *C. gallinacea*, No. 97.) (American)
C. phyllophiloides Pk.
108. Stem attached to rotten wood remnants by long white rhizomorphs, base strigose-hairy, 2–4 cm. long; pileus 2–5 cm., shining-watery-white (moist), sometimes ochraceous-tinged, buff-whitish (dry); gills *short decurrent, very crowded*, narrow, dingy white; spores 4–5 × 2–3 μ. Sometimes with a slight bitter taste (American) ..... *C. eccentrica* Pk.–Kauff.

108. Stem among leaf-mold, cylindrical but mycelioid-thickened at base, not bearing rhizomorphs, 3–7 cm. long; pileus 2–5 (6) cm., white (sometimes tinged tan), with a narrow zone near edge when moist; gills long *decurrent, very narrow*, crowded, white; spores 4–6 × 3.5–4 μ; sometimes with a slight odor (American) ..... *C. adirondackensis* Pk.–Kauff.

109. Growing in woods, usually coniferous; pileus broadly depressed; stem solid 110

109. Growing in open, mossy or grassy places; plants tough, mild, almost inodorous, all parts whitish; pileus convex-plane, then revolute and undulate, *always dry*, even, somewhat shining; gills *adnate* (scarcely subdecurrent), close to crowded, white; stem 2–3 cm. × 3–4 mm., *fibrous*, often ascending, apex mealy (not of Ricken!) (American and European) ..... *C. dealbata* Fr. (*Monogr.*) (Spores subglobose, 4–5 × 3–4 μ; American) ..... *C. sudorifica* Pk.

110. Pileus creamy white or white, obtuse to depressed; gills adnate-subdecurrent, narrow, crowded, white; stem 2–4 cm. × 3–5 mm. long, whitish; spores ovoid, 5–7 × 2–3.5 (4) μ; on débris and needles in spruce and fir forest. (Wyoming, Oregon and Michigan) ..... *C. Robinsoniae* Murr.–Kauff.

110. Pileus whitish (moist), white (dry), *orbicular, regular*; gills decurrent, narrow, crowded, whitish; stem-base enlarged by a spongy mass of mycelioid tomentum, 2.5 cm. × 3–5 mm.; spores 4–5 × 2.5–3 μ. (See No. 101.) (American) .... *C. regularis* Pk.

111. Pileus very small, not over 1 cm. broad 112

111. Pileus 1.5–5 (–6, –7) cm. broad 113

112. Growing on a lichen (Peltigera); pileus *umbilicate*, hygrophanous, grayish-brown and striatulate (moist); gills distant, *narrow;* stem 1–2 cm. × 1.5 mm., concolor; spores 8–10 × 4–5.5 μ (American) ..... *C. peltigerina* (Pk.) Sacc.

112. Growing on the ground, maple woods, in the mountains; pileus *papillate*, pale isabelline; gills distant, *broad*, white, stem 1 cm. × 1 mm., whitish; spores unknown (New York) .... *C. parvula* Murr.

113. Pileus some shade of yellowish, clay color (argillaceous), honey color, leather color (alutaceous), orange or reddish 114

113. Pileus some shade of drab (avellaneous), gray, gray-brown, brown, smoky (fuliginous), or dingy and pale flesh color (not with white, yellow or red shades) 126

114. Gills yellow or yellowish to cream color, sometimes paler in age (orange-reddish in *C. venustissima*) 115

114. Gills white, whitish or pallid, not yellow or creamy-yellowish when young or fresh (discoloring in age, in *C. oregonensis*) 121

115. Growing under conifers, on the ground or on needles; pileus 2–5 cm. broad, not hygrophanous 116

115. Growing on low wet ground, swampy places; pileus *hygrophanous* (!), 1.5–3 cm., dingy yellow (moist), whitish (dry); gills adnate, close; stem 2–3 cm. × 3–4 mm., equal, hollow, concolor; spores not given by Peck (spores 5 × 4 μ, ovoid-subglobose,

echinulate. — Kauff.), gregarious (but see *C. vernicosa*, No. 117) (American) ..... *C. flavidella* (Pk.) Sacc.

116. Pileus neither bright yellow nor orange 117

116. Pileus bright orange-reddish, fading, obtuse or subumbilicate; flesh reddish; gills *subdistant*, decurrent, narrow, concolor; stem 3–4 cm. × 4–8 mm., reddish, equal; spores *large*, 11–16 × 8–10 μ (European) ..... *C. venustissima* Fr.–Rea

117. Spores elliptical, elliptic-ovate or oblong, *smooth;* taste bitter or somewhat disagreeable 118

117. Spores subglobose, *echinulate*, 3–4 μ diameter; pileus honey-yellow to "empire yellow" (R.), fading, convex-plane, margin incurved; stem 2–4 cm. × 3–6 mm., toughish, yellowish, equal, stuffed; gills decurrent, close to almost subdistant, "pale yellow orange" to "capucine-buff" (R.); in forests of conifers (? Syn. *C. flavidella* Pk., see No. 115) (American and European) *C. vernicosa* Fr.–Rick.

118. Pileus coral pink to reddish when young or fresh 119

118. Pileus yellowish-clay color to dingy buff; gills subdistant; stem solid 120

119. Stems subcespitose and *connate by tomentose mycelial matting at the tapering base*, cuticle dull "coral pink" (as on pileus); spores 4–4.5 × 2.5 μ, oblong (Cf. No. 38 *b*) (American and European) ..... *C. socialis* Fr.–Kauff.

119. Stem not connate-tomentose, equal, *whitish*, attached at base by short, spreading white rhizomorphs, often flexuous and compressed, hollow, 3–4 cm. × 3–6 mm.; spores 5–6 × 2.5–3 (3.5) μ, subovate:

(*a*) Cystidia none (!); pileus convex-umbilicate to subinfundibuliform, 2–4 (5) cm., *reddish-incarnate* (moist), alutaceous-chamois (dry), subhygrophanous, the subpubescent margin involute; gills decurrent, crowded, not broad, cream color then alutaceous-yellowish; in conifer forests (European and perhaps American) *C. vermicularis* Fr.–Konrad

(*b*) Cystidia present; pileus 1.5–3 cm., obtuse at first, depressed in age, "vinaceous-cinnamon" (R.) (moist), fading somewhat; gills "light ochraceous salmon," short decurrent, close, distinct; taste rather disagreeable; near tamarack trees in swamp (See full description p. 200.) *C. vermicularis* Fr. forma *cystidiosa*, f. nov.

120. Spores 6.5–8 × 4–4.5 μ, ellipsoid, smooth; pileus clay color (moist), 1.5–3.5 cm.; gills "warm buff" (R.), intervenose; stem *at first covered by a whitish silkiness*, concolor, 2–4 cm. × 3–6 mm.; taste bitter; under pine (See description, p. 193.) *C. fellea* Pk. forma *glabreosa*, f. nov.

120. Spores 4–5 × 3.5 μ, short elliptical to subglobose, smooth, pileus 1.5–2.5 cm., dingy "warm buff" (R.) with slight brownish tints; gills "naples yellow" (R.) from the first, very narrow; stem 3–4 cm. × 2–5 mm., pallid; taste of rancid meal; in conifer woods (See description p. 194.) ..... *C. felleoides*, sp. nov.

121. Gills subdistant, adnate-subdecurrent 122
121. Gills close to crowded, narrow 123
122. Spores ellipsoid, 7 × 4 μ; pileus convex-umbilicate to infundibuliform, *hygrophanous*, pale isabelline (dry?), 2–4 cm.; gills whitish then discolored, narrow; stem 5 cm. × 5 mm., tapering upward, concolor; mixed woods (Oregon) ..... *C. oregonensis* Murr.
122. Spores globose, 3–4 μ; pileus convex-plane or sometimes depressed, alutaceous-yellowish, fading, *not hygrophanous*, 3–5 cm.; gills pallid, broad; stem 4–5 cm. × 4–7 mm., concolor, subequal; frondose woods; odor slight, of anise (European) *C. subalutacea* Fr.–Rick.
123. Odor none; taste mild 124
123. Odor and taste farinaceous; growing on pine needles; pileus convex-plane to subumbilicate or subinfundibuliform, tan color, fading, not hygrophanous, 2–3 cm.; gills subdecurrent, intervenose; stem 1.5–2 cm. × 2 mm., equal, solid; spores 5-6 × 4 μ, elliptic-ovate (American) ..... *C. pinophila* (Pk.) Sacc.–Kauff.
124. Growing on the ground; pileus 3–5 (6) cm. broad, convex to subdepressed 125
124. Growing on mossy logs; pileus 1–2 cm., convex-subexpanded, *hygrophanous*, pale watery isabelline (moist); gills crowded, adnate with tooth; stem 3 cm. × 2.5 mm., mycelioid-enlarged at the base; spores 3.5–5 × 3–4 μ, broadly ellipsoid (New York) ..... *C. subbulbipes* Murr.
125. Stem solid, firm, base spongy mycelioid, often curved, sometimes eccentric, *equal*, 2.5–3.5 cm. × 4–8 mm.; pileus pale buff, deeper-colored on center, sodden; gills decurrent, close, whitish but subcinnamon in age; spores 5–6 × 4–5 μ, subglobose (New York) ..... *C. biformis* Pk.
125. Stem hollow, *rugose*, compressed, 3–4 cm. × 5–10 mm.; pileus *hygrophanous*, dull isabelline (moist?); gills crowded, short-decurrent; spores ellipsoid, smooth, 6–7 × 4–5 μ (California) *C. rugosipes* Murr.
126. Pileus soon becoming regularly cyathiform or subinfundibuliform, *thin or very thin*, hygrophanous 127
126. Pileus not broadly and deeply depressed nor regularly subinfundibuliform, either moist or hygrophanous 138
127. Pileus 3–5 (6) cm., rarely up to 7 cm. broad (See also *C. vibecina*, No. 137 of this Key.) 128
127. Pileus 2–3 (4) cm., or averaging smaller 135
128. Odor and taste markedly farinaceous or bitter and disagreeable .. 129
128. Odor and taste none or slight 130
129. Odor and taste farinaceous; pileus watery reddish-brown (moist), pinkish-buff (dry); gills creamy-whitish; stem 5–7 cm. × 3–4 mm., concolor; spores short elliptical, 6–7 × 4 μ; under pine (Washington) (Cf. No. 133 *a* and *b* of this Key.) (See description, p. 195.) ..... *C. intermedia*, sp. nov.
129. Odor and taste bitter and disagreeable; *plant rigid;* pileus olive-brown to olive-gray, pellucid-striatulate on margin; gills de-

current, almost crowded, sordid yellowish-pallid to grayish; stem 3–7 cm. × 4–8 mm., almost blackish-olive, soon hollow, somewhat tapering up or down; solitary or cespitose; spores elliptical, 7–8 × 3–4 μ; frondose woods (Cf. *C. pruinosa* of conifer forest, No. 131.) (European) . . . . *C. fritilliformis* Batsch–Rick.

130. Basidia apparently 4-spored, spores elliptical; base of stem not with rhizomorphic prolongation 131

130. Basidia 2-spored; spores large, 9–11 (12) × 7–9 μ, subglobose to broadly elliptical; *base of stem abruptly narrowed to a slender rooting prolongation;* pileus blackish-brown, at length punctate-rough to minutely diffracted-scaly; flesh white; stem 5–10 cm. × 6–10 mm., tapering upward, hollow, concolor; gills short acuminate-decurrent, narrow, close to subdistant (Washington to California) See Plate IX. . . . . *C. atrialba* Murr.–Kauff.

131. Pileus glabrous and naked, without a pruinose surface 132

131. Pileus brown, cinerescens, covered with a lead-gray pruina; gills acuminate-decurrent, crowded, narrow, rather pale (dingy whitish or tinged bistre); stem 2.5–5 cm. × 2–4 mm., fibrillose, stuffed, equal, concolor; spores uncertain (6–8 × 2–4 μ, Britz.; 7–8 × 4 μ, Herpell); in conifer forest (European and perhaps American) . . . . . *C. pruinosa* Fr.

132. Spores rather small, not over 6 μ long; gills pallid or slightly tinged with yellowish or cinereous; stem equal 133

132. Spores averaging more than 8 μ long; gills dark colored, gray or brown 134

133. Pileus some shade of brown, umbilicate or subinfundibuliform; stem 3–5 cm. × 3–4 (6) mm., gills decurrent, close, pallid to cinereous-tinted:

(*a*) Stem solid or slightly hollow, slightly fibrillose, concolor; pileus brownish or reddish-brown (moist), whitish (dry), glabrous; spores 5–6 × 3–4 μ (American) . . . *C. subconcava* Pk.

(*b*) Stem stuffed-hollow, compressed, concolor but *with white pruinose silkiness;* pileus firm, pale smoky brown (moist), pale grayish-drab (dry); gills rather narrow; spores oblong, 5–6.5 × 2.5–3 μ . . . . . *C. subconcava* Pk.–Kauff.

133. Pileus olive-gray (moist), whitish or yellowish (dry), umbilicate then infundibuliform, with very thin and wavy margin; gills almost crowded, *pallid or tinged yellowish, very decurrent;* stem 3–5 cm. × 3–4 mm., pallid, stuffed-hollow, often flexuous; spores minute, 3–4 × 2–3 μ; late autumn to winter, on conifer needles (European and American) . . . . . *C. brumalis* Fr.–Rick.

134. Gills distant or subdistant, adnate-decurrent, subjoined at stem, pallid-brownish or soon reddish-brown; pileus coffee-brown ("umber-nigrescens, varying to fuscus or livid," per Fries), when dry more or less canescent; stem 5–7 cm. × 7–12 mm., stuffed-hollow, tapering upward, *fibrillose-reticulate* and brown:

(*a*) Gills distant; spores subelliptic, 8–9 × 5 μ (Ricken); 9–11 × 5–6 μ, elongated-elliptic (Konrad); 10–11 × 5–6 μ, punctate (Rea); "inside and outside of forest, everywhere" (Ricken) (European) . . . . . *C. cyathiformis* (Bull.) Fr. authors

(*b*) Gills subdistant or scarcely close, intervenose; spores punctate-roughish, 7–8 (9.5) × 4.5–5.5 (6) μ (Peck; Kauffman), often on rotten wood, mixed forest, etc. (American) ..... *C. cyathiformis* Fr. forma *americana*, f. nov.

134. Gills crowded, narrow, dark gray with paler edge, thickish, intervenose, acuminate-subdecurrent; pileus *flaccid*, sooty-brown (moist), olive-gray (dry), at length concave; stem 4–6 (8) cm. × 3–6 mm., subincrassate towards base, stuffed-hollow, almost equal, fibrillose, ash-gray; spores 8–10 (11) × 5–6 (6.5) μ, broadly elliptical, smooth; in conifer forests (European and American) ..... *C. concava* Fr.–Kauff.

135. Gills subdistant 136

135. Gills close to crowded 137

136. Spores subglobose, 7–9 × 6–7 μ; pileus deep gray-brown and pellucid-striatulate (moist), grayish-bistre to clay color (dry), margin soon spreading; gills pallid-cinerescent, acuminate-decurrent; stem equal, 3–4 cm. × 3–5 mm., stuffed-hollow, paler; mossy places and moist banks in woods (American and European) ..... *C. expallens* Fr.–Rick.

136. Spores elliptical, 8–9 × 5–6 μ; pileus blackish-olive (moist), bluish-gray (dry), margin at length striatulate; gills gray, thickish, sometimes forked or intervenose, adnate-decurrent; stem 4–6 cm. × 5–10 mm., bluish-gray, silvery-hoary, toughish, hollow; in conifer woods of limestone soil (American and European) ..... *C. obbata* Fr.–Rick.

137. Odor and taste mild; pileus cinereous-fuscous, fading, margin involute; gills *white*, decurrent, narrow; stem 5–6 cm. × 3–5 mm., equal; spores 5–6 × 4 μ, minutely punctate; woods and pastures (England) ..... *C. albo-cinerea* Rea

137. (*a*) Odor and taste farinaceous, often slight; pileus 1–3 cm., olive-brown at length "Saccardo umber" (R.), with paler margin, slowly fading and *center remaining dark*, margin thin and *soon spreading;* gills adnate-decurrent, broadest behind, close to subcrowded, "tileul buff" to "pinkish buff" (moist), not forked; stem 1.5–3 cm. × 2–4 mm., strict, "tawny-olive" (R.), stuffed, base weak and soft; spores oval-subovate, 5–6 × 3–3.5 μ, smooth; on needles of conifers, late in autumn (American) *C. vibecina* Fr.–Kauff.

(*b*) Larger; pileus 3–6 cm., growing in troops in autumn (Spores 5–6 × 3–3.5 μ, Ricken) (European) *C. vibecina* (sense of Fries and Ricken)

138. Pileus not hygrophanous; gills either close or crowded 139

138. Pileus hygrophanous 149

139. Spores globose 140

139. Spores elliptical or subfusiform 142

140. Odor and taste none 141

140. Odor and taste strongly farinaceous; pileus *subviscid* (moist), dull avellaneous; gills decurrent, somewhat crowded, narrow, concolor but becoming dark smoky; stem 3–4 cm. × 4–7 mm., sub-

equal, subconcolor, stuffed-hollow; spores 3–3.5 μ in diameter, smooth (Washington).....*C. brunnescens* Murr.

141. Stem 1–3 mm. thick, elastic, flexuous, gray, shining, apex white-pruinose; pileus *subviscid* (moist), 1–2 cm., gray, fading to whitish; gills grayish, crowded, decurrent; spores 6–7 μ in diameter, smooth; among mosses on banks or in conifer woods (American and European).....*C. hirneola* Fr.–Rick.

141. Stem 7–9 mm. thick, fleshy, mouse-gray, solid, only 2 cm. long; pileus 2–3 cm., smoky-brown; gills short-decurrent, close, rather narrow, mouse-gray; spores 2–3 μ in diameter (Washington) (A stunted form (?) of some plant).....*C. murinifolia* Murr.

142. Pileus umbonate..... 143

142. Pileus not umbonate..... 144

143. Pileus subfulvous, 3 cm., minutely radiate-lineate; gills crowded, pallid, decurrent; stem 6 cm. $\times$ 6 mm., hollow, whitish; spores ellipsoid, 5.5 $\times$ 3.5 μ (under redwoods, California)
C. hondensis Murr.

143. Pileus grayish, 2–4 cm., mammillate; gills crowded, narrow, decurrent, whitish; stem 2 cm. $\times$ 3–5 mm., *eccentric*, solid; spores 8–9 $\times$ 5–6 μ, minutely rough; in grassy places in and outside of woods (European).....*C. dothiophora* Fr.–Rick.

144. Pileus pale watery flesh-color, varying sordid whitish or brownish-tinged in age, 2–5 (6) cm. broad..... 145

144. Pileus with definite brown, brown-gray or gray colors..... 146

145. Pileus *at length concentrically rimulose* on the whitish-hoary surface, not thin; gills *adnate-subdecurrent*, close to crowded, *soon dingy "pinkish-buff"*; stem 3–5 cm. $\times$ 3–6 (7) mm., concolor, fibrous:

(*a*) Gills *broad;* spores elliptic, 3–4 $\times$ 2 μ (Ricken); moist grassy places or in fields and gardens (European)
C. rivulosa Fr. (*Monogr.*)

(*b*) Gills *narrow;* spores elliptic, 4–5 $\times$ 2.5–3 μ, smooth, hyaline; under pine (See description, p. 199.) (American)
C. rivulosa var. *angustifolia*, var. nov.

(*c*) Gills deeply decurrent, narrow, *ashy;* odor farinaceous; spores *pinkish*, 5–6 $\times$ 4–4.5 μ, oval.
(Cf. *Clitopilus novaboracensis* Pk.)

(*d*) Gills deeply decurrent, narrow, white or tinged tan; spores 6 $\times$ 3–4 μ (Rea).....(See *C. senilis* Fr. No. 62)

(*e*) Pileus with whitish-hoary surface, but usually not concentrically rimose; pileus 3–8 cm. broad; gills *rather broad;* spores oval-globose, 4–5 $\times$ 3.5–4 μ, smooth; frequently on very rotten wood and débris (Cf. No. 81 *a* of this Key.) (Syn. *C. phyllophila* Ricken) (Europe and America) see comments.....*C. fraterna*, nom. nov.

145. Pileus without the hoary-white concentric-rivulose surface, obtuse, irregular, colors unchanging; gills crowded, narrow, decurrent, pallid; stem 3–5 cm. $\times$ 5–7 mm., with enlarged-spongy base, elastic, *cylindrical*, stuffed, pallid; spores minute, 4 $\times$ 2 μ; in conifer forest (European).....*C. paropsis* Fr.–Rick.

146. Odor and taste bitter or subnauseous, distinct; pileus 4–6 cm. broad 147
146. Odor and taste mild (*C. morbifera* Pk.–Kauff. may be looked for here.) 148
147. Spores subfusiform, 8–10 × 3–4 μ; pileus ashy-gray, fading to subalutaceous, the at first involute margin pubescent; gills crowded, easily separable, variously adnate-subdecurrent, whitish to cinereous; stem 4–6 cm. × 8–10 mm., solid, *concolor*, fibrillose-tomentose; mossy places, edge of woods (European) *C. inornata* Fr.–Bres.
147. Spores elliptical, 5–6 × 2–3 μ; pileus brownish to fawn color, shining (moist), crenate-wavy on margin; gills crowded, adnate-subdecurrent, pallid tinged grayish; stem 3–5 cm. × 3–5 mm., equal, stuffed, pallid; in meadows and heaths (European) ..... *C. amarella* Fr.–Rick.
148. Stem white-mealy throughout, solid, narrowed downwards, 3–5 × 6–7 mm., pallid; gills crowded, pallid, subdecurrent; pileus 3–5 cm., with spreading margin, obtuse; spores 6–7 × 4 μ; under willows in the mountains (European) ..... *C. luscina* Fr.–Rick.
148. Stem glabrous and naked, attenuated upwards, elastic, smoky umber, 4–7 cm. × 6–15 mm.; gills crowded, adnate-decurrent, white; pileus smoky umber to blackish, glabrous, obtuse; spores 6–7 × 4 μ; conifer woods (See No. 75 *c.*) (European) *C. comitalis* Fr.–Rea
149. Gills grayish to dark gray or definitely tinged with gray, ashy, olivaceous or brownish-gray, pileus 2–4 (5) cm. broad 150
149. Gills whitish, pallid, merely tinted with flesh-color or cream-color 155
150. Spores globose or subglobose 151
150. Spores ellipsoid to subfusiform-elliptical 153
151. Odor and taste not farinaceous; pileus not umbilicate 152
151. Odor and taste farinaceous; pileus brownish-gray (moist), dull gray (dry), the striate margin incurved, usually convex-umbilicate then plane ("at length inverted, infundibuliform and undulate lobed," per Fries); gills adnate to decurrent, rather narrow, crowded, *dark gray;* stem 3–4 cm. × 4–6 mm., *gray*, soon hollow, often compressed, sometimes eccentric, base forming enlargement with intergrown needles; in conifer forest; spores 2–3.5 μ in diameter (American and European) *C. ditopoda* Fr.–Rick.
152. Spores 3–4 μ in diameter; odor and taste slight, fruity; pileus ashy then olivaceous (moist), subochraceous (dry), convex to plane-depressed; gills *broad*, broadly adnate, very crowded, verging to olivaceous in age; stem 5–7 cm. × 2–4 mm., tough, somewhat hollow, striate, ashy; in pine forests (European) *C. pausiaca* Fr.–Rea

(*a*) Spores 5–6 × 4–5 μ, subglobose; odor and taste mild; pileus brown or grayish-brown, convex to plane-depressed, sometimes concentrically rivulose, the pruinose margin involute; gills close, adnate-decurrent, ashy or

tinged yellowish; stem 2–5 cm. × 2–4 mm., solid, grayish-brown; in bushy places and pastures (Cf. *C. vibecina*, No. 137 *a*) (American) ..... *C. vilescens* Pk.

(*b*) Spores "globose, echinulate, 7 μ diam." (Sacc.), pileus olive-gray, naked, coin-shaped, not umbilicate; gills *lead-gray*, crowded, adnate or slightly subdecurrent; stem 5–6 cm. × 2–4 mm., bent, elastic, hollow, concolor; odor and taste none; heathy places in conifer forest (European) *C. obola* Fr.–Rick.

153. Stem 2–5 mm. thick, equal 154

153. Stem 5–10 mm. thick, tapering upward from an enlarged base, 6–7.5 cm. long, spongy-stuffed, terete, tough, gray; pileus very obtuse, orbicular, smoky-gray, the even margin spreading; gills adnate or subdecurrent, *broad* (Fries), pale, grayish-whitish; in conifer forest; odor and taste none; spores unknown (6–7 × 3–4 μ Sacc.) (European) ..... *C. orbiformis* Fr.

154. Spores 5–6 × 3–5 μ, broadly ellipsoid; pileus convex to depressed; gills brownish-gray, narrow; stem 2–3 cm. × 2–4 mm.; "among fallen leaves in woods" (otherwise as No. 143 of this Key) (Cf. 137 *a*, *C. vibecina*) ..... *C. ditopoda* Fr.–Pk.

154. Spores ellipsoid-subfusiform, 7–8 × 3–4 μ (elliptical, 6 × 3 μ, per Rea); pileus brownish-gray (moist), pallid-whitish (dry), *not umbilicate*; gills adnate, crowded, pale gray; stem 2–5 cm. × 3–5 mm., stuffed-hollow, *pulverulent-hoary*, tough; odor and taste mild; in conifer forest (European and American) *C. metachroa* Fr.–Rick.

155. Odor pleasant, of anise, or farinaceous (sometimes slight) 156

155. Odor none or slight, at least not farinaceous nor of anise 158

156. Gills close or crowded; odor of anise 157

156. Gills subdistant, short-decurrent; odor and taste strongly *farinaceous*; pileus umbilicate, 2–3.5 cm., very pale avellaneous (dry!); stem 3–4 cm. × 2–4 mm., equal, toughish, pallid, nearly solid; spores ovoid, 6–8 × 3–5 μ; in frondose woods (Eastern United States) ..... *C. farinacea* Murr.

157. Gills broad, crowded, adnate-subdecurrent; pileus 3–5 cm., livid to livid-grayish (moist), isabelline (dry), at length irregularly depressed; stem 3–5 cm. × 5–8 mm., at length striate, stuffed-hollow, often compressed, pallid; densely gregarious-subcespitose; in frondose and conifer woods; spores 6–7 × 3–4 μ (European) *C. obsoleta* Fr.–Rick.

157. Gills broadly adnate, subdecurrent, close to subcrowded; pileus 2–4 (6) cm. broad, umbilicate or depressed, pale "avellaneous" *with abruptly darker umbilicus* (moist), whitish (dry); stem 3–5 (6) cm. × 3–5 (7) mm., stuffed-hollow, pallid; in mixed forest; spores 6–7 × 3–3.5 μ (United States and Europe) *C. suaveolens* Fr.–Kauff.

158. Gills close or crowded, usually narrow 159

158. Gills distant and broad, adnate, whitish; pileus olive-gray and striate (moist), shining-whitish (dry); stem 5–8 cm. × 3–5 mm.,

equal, hollow, shining-whitish; spores ellipsoid, 6–7 × 3–4 μ; moist place under conifers (European)
C. difformis Fr.–Rick. (*non* Schum.)

159. Not growing attached to needles 160

159. Growing attached to needle-beds in pine woods, base of stem intergrown-mycelioid; stem terete or compressed; the center of the pileus umbilicate or depressed and *persistently darker*, subhygrophanous; gills subdecurrent, not pure white; odor and taste mild; often appearing in arcs or circles:
(*a*) Spores 4–5 × 2.5–3 μ, elliptic-oblong; pileus 2–4 (5) cm., color when moist varying pale drab to watery dingy incarnate or pale watery clay color, pinkish-buff (dry); gills adnate-subdecurrent, variable in width, narrow to broadish (2–4–6 mm.), close to subcrowded, tinged drab when young, *at length pale ochraceous buff;* stem 2–4 cm. × 3–5 mm., *hollow*, terete or compressed, concolor (European and American) .... *C. diatreta* Fr.–Kauff.
(*b*) Spores 5–7 × 2.5–3 μ, narrowly oblong; pileus 2–5 (7) cm., colors much as in (*a*); gills pinkish-buff to pale ochraceous-buff; stem 2–4 (5) × 3–7 (9) mm., at first tinged drab then always fuscescent downwards (See description, p. 192.)... *C. diatreta* Fr. var. *fuscescentipes*, var. nov.
(*c*) Spores 5–6 × 3–3.5 μ, elliptical; pileus 2–5 cm. broad, "pinkish cinnamon" (R.) at first, "clay color" at maturity, fading; gills remaining pallid; stem 3–4 cm. × 3–5 (7) mm., enlarged-mycelioid at base; without definite odor or taste; otherwise like *C. regularis* (See description, p. 198.) ..... *C. regularis* Pk. var. *insistens*, var. nov.

160. Stem pale colored, i.e. pale grayish-brown, whitish or tinged straw-color 161

160. Stem umber-brown (moist), equal, 2–4 cm. × 2–4 mm., stuffed, terete or compressed; gills narrow, very crowded, adnate with tooth; *pileus umber-brown tinged chestnut* (moist), 2–3 cm., alutaceous yellow (dry), not umbilicate, sometimes eccentric; spores 4–5 × 2–3 μ, elliptical; in grassy or bushy places, frondose woods (European) ..... *C. mortuosa* Fr.–Rick.

161. Stem 4–7 mm. thick, tapering upwards; pileus 3–6 cm. broad .. 162

161. Stem 2–3 (4) mm. thick, 2–3 (4) cm. long, equal or subequal, stuffed-hollow, terete or compressed, concolor; pileus grayish-brown or brownish (moist), whitish (dry), 1–3 (4) cm. broad; gills adnate or slightly decurrent, close, whitish:
(*a*) Odor and taste farinaceous; center of pileus darker and subumbilicate (moist); stem stuffed-hollow; spores 6 × 3 μ (American) ..... *C. albidula* forma *centralis* Pk.
(*b*) Odor and taste none or slightly farinaceous; pileus subdepressed or subumbilicate; stem stuffed-hollow; spores 5–6 × 4–4.5 μ. Specimens becoming pale tawny yellowish when they are dried out (See No. 104.) (American)
C. compressipes (Pk.) Sacc.

(*c*) Odor and taste not farinaceous; pileus convex-plane to subdepressed, white to alutaceous when dry; stem solid, pruinose-subfibrillose; spores oval, minute, 5×3 μ, smooth. **Poisonous.** (Cf. C. sudorifica Pk.) (American).....*C. morbifera* Pk.–Kauff.

162. Pileus grayish-straw color, umbilicate-depressed; gills short-decurrent; stem 3–4 cm. long, stuffed-hollow, glabrous, concolor; spores broadly elliptical, $5–6 \times 4–5$ μ (Washington and Oregon).....*C. Peckii* Murr.

162. Pileus "apricot-buff" to "vinaceous-cinnamon" (R.) with fulvous tinge (moist), convex-plane to depressed or subinfundibuliform; flesh scissile; gills narrow, subdecurrent, whitish or tinged with color of the pileus; stem *solid*, concolor, 2–4 cm. long; spores narrowly ellipsoid, $6–7.5 \times 3.5–4$ μ (Oregon and Washington) (Cf. No. 119.).....*C. cuticolor* Murr.–Kauff.

New Species, Varieties and Forms of Clitocybe

Among the considerable number of clitocybes which I have collected throughout the United States during the last twenty years, not all could be opportunely studied in detail and at times had to be discarded in favor of more pressing work; this was especially true in distant places and at times when collecting was good and my work table overflowed with too many things to take care of. Hence a number of American undescribed species may have been in this way shamefully neglected. At Ann Arbor, however, as already stated (p. 156), continued studies of the same area with especial reference to this genus disclosed a number of plants, which, although often close to described European species, nevertheless possessed characters which barred them from direct entrance into known species. These characters, with the exception of spore size and shape, were scarcely sufficient in number or important enough in degree to warrant specific distinction, but yet they were different — often by their spores. It seems desirable to take a conservative attitude and report these as new varieties or forms. Three new species, however, have been delimited. In all, ten additions to the group are presented below.

Clitocybe compressipes Pk. forma **autumnale,** f. nov.

(See No. 104 of Synopsis)

This differs from the typical form in stem characters. The

stem is stouter, 4–6 (7) mm. thick, and becomes "ochraceous buff" (R.).

Microscopic characters: Spores elliptic-ovate, smooth, hyaline, 4.5–5.5 × 3–3.5 μ; cystidia none; edge of gills homomorph, i.e. without differentiated sterile cells; basidia 4-spored; gill-trama subinterwoven.

Secondary characters: Pileus scarcely hygrophanous, convex, becoming irregularly expanded-depressed or repand-lobed, pliant and with a slight hoariness when moist; flesh subscissile, thin, concolor. Gills white at first, becoming tinged with cream-buff color; stem almost glabrous, base white-hairy to substrigose and attached to mats of oak and other leaves, changing from white to "ochraceous buff" or darker, usually dilated at apex. Odor and taste none or very slight. Gregarious or subcespitose. After stem is dried the color fades to dull white.

Abundant during October, 1926, in the oak woods about Ann Arbor, but not many individuals in one place.

Clitocybe cyathiformis Fr. forma **americana,** f. nov.

(See No. 134 of Synopsis)

This differs from the European species in its gills being merely close to subdistant and intervenose. It often occurs on rotten wood. The European descriptions uniformly refer to a species with "distant" gills. Spores measure 7–8 (9) × 4.5–5.5 μ.

The whole group to which this belongs needs further study in this country. Whether we have *C. pruinosa* or *C. fritilliformis* is not certain, in part because the microscopic characters of these European plants are not fully recorded. *C. concava* Fr. with crowded gills and large spores occurs at least in the Northwest. *C. subconcava* Pk. differs from both *C. cyathiformis* and *C. concava* by its distinctly smaller spores.

Clitocybe diatreta Fr. var. **fuscescentipes,** var. nov.

(PLATE X)

(See No. 159 of Synopsis)

This differs from the species itself by its longer spores, larger pileus and stouter stem which becomes fuscous.

Microscopic characters: Spores narrowly oblong, smooth, hyaline, 5–6 (7) × 2.5–3 μ; cystidia none; edge of gills homomorph; basidia 4-spored, 30 × 4–5 μ; gill-trama subinterwoven.

Secondary characters: Pileus with fuscous centre when young, umbilicate to umbilicate-depressed, the darker color of centre persistent after fading elsewhere, glabrous and naked, at length pliant, even or nearly so (moist); flesh thin (about 2 mm. thick), watery then whitish, subscissile; very young margin of pileus incurved, thin, soon spreading. Gills arcuate, generally acuminate to both ends, rather narrow (3–6 mm.), not crowded; stem hoary-pubescent or pruinose-silky above, strongly white-mycelioid or tomentose at base, even or furrowed-compressed. Odor, if any, slight and pleasant. Usually in circles in a gregarious or subcespitose manner, under pine in plantations.

Type collected November 15, 1926, northeast of Ann Arbor, Michigan, by C. H. Kauffman.

It seems that this variety has in part characters of both *C. diatreta* Fr. and *C. brumalis* Fr., being nearer the former by its colors and because its gills are less decurrent and not as strongly narrowed as in *C. brumalis*. It has, however, many of the main characters of *C. brumalis* of the form A on pine needles, as given by Fries in *Monographia*. In fact, it appears to fit well the *C. brumalis* as given by Rea (24). Compare also *C. albidula* var. *centralis* Pk. which, however, has a distinct farinaceous odor and taste. The shades of color present under different weather conditions, in both *C. diatreta* and the variety, are very exasperating.

Clitocybe fellea Pk. forma **glabreosa,** f. nov.

(See No. 120 of Synopsis)

This form differs from the typical form in its glabrous pileus, the whitish silky surface of the young stem, and by its creamy-yellowish, i.e. "warm buff" (R.), gills. (Compare *C. felleoides*, sp. nov.)

Microscopic characters: Spores elliptical, smooth, hyaline, 6.5–8 × 3.5–4.5 μ; cystidia none; edge of gills homomorph; basidia 4-spored, 45 × 5 μ; gill-trama subinterwoven.

Pileus 1–3.5 cm., convex then depressed to umbilicate, "clay color" (R.) (moist), "light ochraceous buff" (dry), glabrous, with dull lustre, even, dry, rather brittle; margin subincurved, remaining decurved, thin; flesh white or whitish. Gills rather decurrent, narrow, subdistant, "warm buff" (R.), thickish, *intervenose*. Stem 2–4 cm. × 3–6 mm., equal or slightly tapering downwards, *solid* but often compressed-furrowed, terete in smaller plants, *same color as the pileus*, covered at first by a white silkiness, rigid-brittle, white-mycelioid at base. Taste *distinctly bitter*, odor slight, subrancid. Gregarious or subcespitose.

Under pine in plantations, October 18, 1926, northeast of Ann Arbor, Michigan. Collected by C. H. Kauffman.

Clitocybe felleoides, sp. nov.

(See No. 120 of Synopsis)

This species differs from *C. fellea* Pk. by its much smaller spores, glabrous pileus and by the gills which have a "naples yellow" (R.) color from the first. It differs from *C. fellea* form *glabreosa* by its smaller spores and by its tough, fibrous-splitting stems which are attenuate downwards, and by the paler colors of pileus and stem.

Microscopic characters: Spores 4–5 × 3.5 μ, short and broadly elliptical, rounded-obtuse at ends, smooth, hyaline; cystidia none; edge of gills homomorph; basidia 4–spored; gill-trama more or less interwoven.

Pileus 1–2.5 cm. broad, subplane and umbilicate from the first, firm or subrigid, at first watery buff, soon dingy "warm buff" (R.), subhygrophanous, even, glabrous; margin at first incurved and white-hoary-silky, at length elevated. Gills arcuate-subdecurrent to decurrent, *subdistant* and distinct, subrigid, very narrow, rather thin, a few forked, "naples yellow" from the first, edge entire. Stem 3–4 cm. long, 2–4 (5) mm. thick, slightly tapering downwards, pallid, *solid*, tough, fibrous and splitting lengthwise, more or less scurfy. Taste of rancid meal or bitter, odor slight and similar.

Type collected under pines in plantations, near Ann Arbor, Michigan, August 23, 1925, by C. H. Kauffman.

Clitocybe gilvaoides, sp. nov.

(PLATE XI)

(See No. 68 of Synopsis)

This species differs from *C. gilva* Fr.–Authors, by its differently shaped spores, which are smooth instead of echinulate, the more rufous color of pileus and gills, the solid stem and the more infundibuliform pileus at maturity. Other close relatives also have echinulate and globose spores according to European authors.

Microscopic characters: Spores oval-elliptical, *smooth*, hyaline, 5–6 × 3–3.5 μ; cystidia none; edge of gills homomorph; basidia 4–spored, 30 × 6 μ.

Pileus 4–8 cm. broad, fleshy, convex-expanded then depressed to concave or subinfundibuliform, "rufous" (R.), glabrous, even, moist, sometimes faintly marbled-spotted in places; margin involute, becoming wavy-repand in large specimens; flesh rather compact, watery-pallid (moist), toughish but splitting radially. Gills deeply decurrent, narrow, very crowded, forked, ochraceous-rufous ("capuchin-buff" R.). Stem 3–4 cm. × 3–6 mm., firm but elastic, *solid*, equal or slightly spongy-enlarged at base, glabrescent, concolor. Odor and taste mild. Gregarious-subcespitose.

Type collected in mixed conifer forest in deep moss, at Seventh Lake, Adirondack Mountains, New York, September 2, 1921. A previous collection had been made at North Elba, in the Adirondacks in 1914 and reported (9) as *C. gilva* Fr.

I have never found the typical European *C. gilva*, nor the related species, *C. splendens*, *C. flaccida* and *C. inversa*, all of which are said to have globose and echinulate spores. In most respects our species is as close to *C. inversa* as to *C. gilva*, but cannot be forced into either. Doubtless the notices of Peck (23) are of this plant.

Clitocybe intermedia, sp. nov.

(See No. 129 of Synopsis)

This species differs from *C. frittilliformis* and *C. subconcava* by the farinaceous odor and taste, by the different colors of pileus

and stem and other stem characters; and from others of its relatives by its odor, taste and gill characters, and by the spores. It forms part of a series of species constituting a close knit group.

Microscopic characters: Spores short-elliptical, smooth, hyaline, 6–7 × 3.5–4 μ; cystidia none; basidia 4-spored; gill-trama parallel.

Pileus 3–4 cm. broad, soon plano-umbilicate, at length umbilicate-subinfundibuliform, "orange cinnamon" (R.) i.e. watery reddish-brown (moist), *even*, *glabrous*, "pinkish buff" (dry), very hygrophanous; margin at first incurved, soon spreading and thin; flesh thin, scissile, concolor. Gills ascending-decurrent, close, not crowded, narrow, "ivory yellow" or pallid, thin, edge entire. Stem 5–7 cm. × 3–5 mm., slender, slightly incrassate downwards, stuffed then hollow, subterete to compressed-furrowed, same color as the pileus, glabrous, innately subsilky upwards. Odor and taste markedly *farinaceous*. Gregarious.

Type collected at the edge of a conifer forest near a stream at Lake Quiniault, Olympic Mountains, Washington, October 17, 1925, by C. H. Kauffman.

Clitocybe odora Fr. var. **pacifica,** var. nov.

(See No. 56 *d* of Synopsis)

This variety is distinguished by the deep green to olive, forking or anastomosing gills. Its spores tend to be longer than in the other American forms and have a tint of green.

Microscopical characters: Spores narrowly oblong, sometimes more elongated, smooth, hyaline or with a faint tinge of green, 6–8 (–9–10) × 3–4 μ; cystidia none; basidia 4–spored.

Secondary characters: Pileus "grayish-olive" to "deep grayish olive" (R.); when moist, fading to light greenish, or assuming brownish tints on drying and then becoming hoary in appearance, glabrous and even; flesh concolor, thin. Gills adnate, at length slightly decurrent, 5–6 (7) mm. wide, narrowed at both ends, venose. Stem 5–7 cm. × 6–12 mm., sometimes more slender, soft when wet, fibrous-fleshy, "isabella color" (R.) when moist. Odor strongly fragrant, of anise, sometimes nearly lacking; taste slight to somewhat disagreeable.

In young unexpanded fresh plants the pileus is rigid, the surface has a gelatinous feel and is deep olive-green like the gills; the stem is whitish.

Type collected in mixed forest of oak, fir and shrubs at Takilma (Siskiyou National Forest), Oregon, December 1, 1925, by C. H. Kauffman.

An abnormal form (monstrosity) of this plant was found and studied in detail before finding the normal variety. It was characterized by an extreme development of the veining and anastomosing of the gills so as to cause their deformation to some extent, disturbing their natural development, and producing very thick gills approaching the appearance of those of Cantherellus, while the margin of the pileus became folded and crenate-lobed as a result of the tensions produced. The colors tended to be much more blue than green. They had a strong odor of anise. The spores were inclined to be shorter, green tinged, 5–7 × 3–4 μ; basidia 4-spored. It was seen on two occasions, growing in mixed forest like the var. *pacifica*.

The description which I made of these abnormal plants would fit exceedingly well that of the genus "Chlorophyllum" Murrill (*North American Flora*, Vol. 9, p. 172), a genus based on a tropical, South American species, viz. *C. viride* Pat. Incidentally, the name Chlorophyllum Massee antedates Murrill's name. Whether that tropical species is also a monstrosity of some normal form, due either to very wet weather conditions or to a parasite, both of which were possible agents in the case of my plants, it would be mere guessing to say. Since I was able to demonstrate all sorts of intermediates between the monstrosity and the variety *pacifica*, and the odor is distinguishing, no doubt remains as to its identity with *C. odora* var. *pacifica*.

Clitocybe regularis Pk. (Emended)

(See Nos. 101 and 110 of Synopsis)

N. Y. State Mus. Bull. 54. 948, pl. K, figs. 1–7. 1901.

Microscopic characters: Spores oval, smooth, hyaline, 4–5 × 3 μ; cystidia none; edge of gills homomorph; basidia 4-spored,

with prominent sterigmata which are 2–2.5 μ long; gill-trama parallel, the hyphae about 5 μ diameter.

Pileus 2–5 cm. broad, subpliant, thickish on disk, *very regular*, broadly convex, soon plane or slightly depressed, whitish, i.e. "ivory yellow" (R.) when moist and even, *covered with a silky pulverulence and white when dry*, otherwise glabrous; margin at first incurved and obsoletely tomentulose; flesh watery-pallid to white, thin. Gills adnate to acuminate-subdecurrent, narrow, crowded, whitish, i.e. "tileul-buff" (R.) at first, almost "cream-buff" in age, edge entire. Stem 4–5 cm. × 5–7 mm., firm when fresh, the *base enlarged by a spongy mass of mycelioid tomentum* and intergrown with pine needles, etc., *solid* but with spongy axis, cortex thick and tough, equal above base, terete, glabrous to pruinose or slightly subtomentose upwards. Odor and taste of *anise*. Gregarious.

In pine plantations of white pine, Ann Arbor, Michigan, August 23, 1925.

Clitocybe regularis Pk. var. **insistens**, var. nov.

(See Nos. 101 and 159 *c* of Synopsis)

This variety differs from the typical form mainly by the spores, which are elliptical, smooth, and measure 5–6 × 3–3.5 μ, by the lack of any notable odor or taste, and by the prevailing color. When young and moist the pileus is watery "pinkish cinnamon" (R.), becoming pale "clay color" at maturity but fading somewhat after losing moisture; the young gills are "vinaceous buff," later "pinkish buff." The stem characters, including the enlarged mass at the base, are like the typical plants. It forms circles and arcs in pine plantations, where the base of the stem is intergrown with the needles.

Type collected near Ann Arbor, Michigan, October 18, 1926, by C. H. Kauffman.

This form has some of the distinguishing characters of *C. diatreta* and its variety and is easily confused with them. The centre of the pileus lacks, however, the persistently darker shades of those forms, the spores are elliptical instead of narrowly

oblong, and the stem is spongy-solid within, instead of hollow; the caps do not become rivulose-rimulose on the surface as in *C. rivulosa.* It forms "fairy rings" like *C. diatreta,* and has the enlarged mycelioid base of stem like *C. regularis.*

Clitocybe rivulosa Fr. var. **angustifolia,** var. nov.

(PLATE XII)

(See No. 145 *b* of Synopsis)

This differs from the typical form as described by Fries in *Monographia* (Vol. 1, p. 108), and by other European authors mainly by its gills never being broad enough to be called "broad"; in fact the gills are truly narrow. Its spores also seem to be different from the size given in European notices. Peck (21) has already noted the discrepancy existing in the narrowness of the gills of the American form. The European species seems to grow only in open places, while our variety occurred in a distinct conifer habitat.

Microscopic features: Spores elliptical, 4–5 × 2.5–3 μ, smooth, hyaline; cystidia none; edge of gills homomorph; gill-trama of parallel hyphae.

Pileus rather firm, 2–6 (7) cm. broad, sometimes slightly depressed in age, or subumbilicate, mostly obtuse and plane, whitish-incarnate, covered at length with an adnate *pruinose-hoariness, becoming concentrically rimulose-rivulose* from the delicate cracking of the hoary surface layer; margin not striate, at first incurved and minutely silky-tomentulose, then *inflexed,* rather obtuse; flesh thickish on disk, abruptly thin half-way to edge of pileus, scarcely subscissile, concolor. Gills subdecurrent, *narrow* (3–4 mm.), of uniform width except the acuminate ends, crowded, dingy "pinkish buff" (R.), thin, at length subarid, edge entire. Stem 2–3 (4) cm. × 3–6 (7) mm., equal down to the *enlarged tomentose-mycelioid base,* colored like pileus, varying from pubescent-floccose at apex to unequally tomentulose downwards, *stuffed-hollow,* terete, cortex fibrous-toughish. Odor and taste mild. Subcespitose-gregariously arranged in arcs and circles for the most part.

Type collected on needle beds in pine plantations near Ann Arbor, Michigan, October 5, 1924, by C. H. Kauffman.

Common in the late fall in these plantations. The base of the stem arises from the soil below the needles. In the cool weather the plants remain *in situ* for quite a while, and the pileus at length becomes irregularly undulate-lobed as in *C. diatreta*. The hoary and later concentric-rivulose character of the pileus is found also in *Clitopilus novaboracensis* and *Clitocybe senilis*. The colors and non-umbonate pileus separate it from *C. tornata*, the pileus of which is also white-hoary and in wet weather may become rimulose. The young pileus of *C. rivulosa* is convex but quickly subplane and in this firm condition, a thin, subgelatinous pellicle can be removed from its surface. The flesh is somewhat sodden in rainy weather. The incurved margin of the pileus is closely pressed against the young gills, and on spreading may have noticeable crenate-striate marks. In the younger plants the hoary surface character is lacking, later the color of the surface, beneath the whitish-hoariness is pale-pinkish-aluta-ceous. The typical, broad-gilled plant has apparently not been found in this country.

Clitocybe vermicularis Fr. forma **cystidiosa**, f. nov.

(PLATE XIII)

(See No. 119 of Synopsis)

The distinguishing feature of the species, in contrast to its near relatives, is the short branching system of white strands (rhizomorphs), which spread from the base of the stem into the substratum, sometimes only slightly in evidence. The *form* here described differs mainly in the presence of cystidia, the smaller size of the pileus as compared with the size usually given, and slightly in color. It is possible that the cystidia have heretofore been overlooked in the typical form by authors. The main characters of both are given in the synopsis.

Microscopic characters: Spores elliptical-subovate, smooth, hyaline, 5–6 × 3–3.5 μ; cystidia scattered among the basidia and rather few in most sections, narrowly lanceolate, very thin

walled, apex subobtuse, slender pedicillate, 50 × 5–6 μ; basidia 4-spored, about 27 × 5 μ; gill-trama parallel or nearly so.

Secondary characters: Pileus rather firm, at first subconvex, color deeper when young and moist. Gills 2–3 mm. broad, edge entire, separable from the trama of pileus. Stem as in the typical form.

Collected under tamarack trees in low swampy ground, August 14, 1921, near Ann Arbor, Michigan.

Comments on Some Species

The group containing *C. aggregata, C. connata, C. multiceps, C. cartilagineum, C. conglobata* and their forms and synonyms have been in part placed in Tricholoma by some authors. Since they are intermediate between the two genera, nothing is gained by being dogmatic in the matter. They are here kept in Clitocybe for practical reasons and because the gills are usually in part — often for the most part — somewhat decurrent. The European forms have been critically discussed by Bresadola (3) and by various authors, and disagreement as to the synonymy of a number of the older species, here excluded, seems to have a fair chance of being continued indefinitely. The cause of a large part of this disagreement seems to be the great variability of most of these species and the chance secondary characters they may have under local conditions during their development.

C. candicans Fr. (see No. 101 of Synopsis). — Commonly as this species is reported, it seems poorly known and often confused with others. The cartilaginous nature of the stem when in good vigor easily leads one to the genus Omphalia.

C. candida Bres. and the others of its near relatives, like *C. gigantea*, are discussed in *Agaricaceae of Michigan* (10).

C. cerussata Fr. (*Monographia*) (see No. 54 of Synopsis). — This cannot be the plant described by Ricken (25). The latter differs by its umbonate pileus whose surface is not covered by a satiny-pruinose bloom, by the broader gills and the brunnescent stem. Ricken's species has been well described by Peck (22) under the name *C. nobilis*, showing that it occurs both in

Europe and the United States. *C. albissima* Pk. may be confused with the Friesian species, but its gills become lutescent in age or on drying, while Fries says those of *C. cerussata* "are never lutescent." Peck's "*C. cerussata*" (23) is also different by reason of its subglobose spores. I have collected *C. cerussata* Fr. twice in the Adirondack Mountains, once in 1914 and again in 1921. The latter collection came from the same locality (Seventh Lake), from which the specimens studied by Blizzard (1) came, and which were undoubtedly determined by Professor Atkinson.

C. EXPALLENS (Pers.) Fr. (see No. 136 of Synopsis). — It is agreed by both Ricken (25) and Konrad (16) that this Persoonian species is recognizable from *C. vibecina* Fr. by its larger almost subglobose spores, which measure 7–9 × 6–7 μ; and that *C. cyathiformis* differs from *C. expallens* also by its spores, which are ellipsoid and measure 9–11 × 5–6 μ. These opinions give this species a much better status than it has hitherto had. *C. cyathiformis* forma *americana* (see No. 134 *b* of Synopsis), which has similar spores, is however not *C. expallens* unless the European descriptions of *C. cyathiformis*, as to gill and spore characters, include more than one species.

Clitocybe fraterna, nom. nov. (see No. 145 *e* of Synopsis). *Clitocybe phyllophila* Ricken (*Blätterpilze*, part 5: 365, 1914). — What is surely identical with Ricken's account is a plant occurring near Ann Arbor. On the other hand, there occurs in the United States, mostly solitary and usually on rotten wood, what seems to be clearly the species of Fries, carefully described by him in *Monographia* (see No. 81 of Synopsis). These two species differ somewhat in size but more especially by their spores. It seems desirable to give a name to one of these, namely, the species of Ricken, and retain *C. phyllophila* Fr. for the other one.

The spores of *C. fraterna* are subglobose, smooth, 4–5 × 3–4 μ, while those of *C. phyllophila* in sense of Fries; of Rea in England; of Peck and myself in the United States, are elliptical, smooth, 5–7 × 3–4 μ.

CLITOCYBE GALLINACEA Fr. (Plate XIV; see No. 97 of Synopsis). — This rare species has been reported twice in the

United States, once by Peck, and I listed it from Mount Hood, Oregon (13). The latter collection certainly is very close to the Friesian species. The taste, at first tardily peppery, is persistent in the mouth, becoming quite sharp and is felt for hours afterwards. Fries states that the pileus is always obtuse; in my specimens the younger were obtuse, becoming depressed to bowl-shaped during expansion or in age. The "irrigate-pruinose" character of the surface of the pileus and stem is very marked. Although Fries reported the stem solid, it is really only firmly stuffed in the younger plants, and eventually may become hollow. The gills are easily separable from the trama of the pileus. Cystidia are lacking; the edge of the gills is homomorph and the gill-trama is composed of parallel hyphae. The size of the pileus of the Mount Hood plants was 3–5 (7) cm., which is larger than Fries assigned to it; he gives the size 1.5–2.5 cm., but remarks that "it is little known, perhaps . . . fictitious." Ricken reports it. Whether Rea's plant (24), with a "bitter" taste, is the same, is doubtful. Peck's specimens also were reported as only "bitter and unpleasant" (20), and are not likely to have been the same as the Oregon plant.

C. GEOTROPA Fr. (see No. 70 of Synopsis) is rapidly, at the hands of recent European mycologists, losing its status as a distinct species. Ricken and others consider it to be identical with *C. maxima* Fr. On the other hand the English mycologists retain it in their flora, and Rea (24) reports the spores as being "subglobose, 5–7 μ in diameter." *C. maxima,* as known to me (see *Agaricaceae of Michigan*), is a different plant; I have it from the Rocky Mountains as well as from Michigan. Its spores are ellipsoid, and measure 7–8 × 5–5.5 μ. In southern Michigan it occurs near tamarack, in Colorado under pines. *C. geotropa* differs from the latter in its "*very glabrous* pileus," which is white at first then "lutescent," and by its different spores. According to Fries the pileus is 3–7.5 cm. broad, but extremely large sizes have been reported under this name by later European writers, owing perhaps to misdetermination of the species at hand. I have a specimen which I collected in Sweden, which Romell referred to *C. geotropa,* and whose pileus did not exceed

the size given by Fries. The spores are oval-globose, 6–7 × 5–6 μ, punctate. This evidently agrees with the conception of the species known to the British mycologists.

C. ILLUDENS (Schw.) Sacc. (see No. 2 of Synopsis). — This well-known large American species, with its outstanding orange-red color and luminescent characteristics, has been generally considered as exclusively American. Recently, however, Konrad (*Bull. trimest. Soc. Mycol. de France*, 39: 3, 1923) seems to assume that it is a synonym of *Clitocybe olearia* (DC.) Maire. This latter species is *Pleurotus olearius* Fr. and, according to Quélet, it is also *Pleurotus phosphoreus* Batt. This European plant has a southern distribution, being found in the Mediterranean countries, but may occur as far north as Switzerland and France, and, like ours, is poisonous.

Konrad says, however, that *C. olearia* may be confused with *Cantherellus cibarius* "dont il a la couleur." One who knows the American plant at all would indeed have a vivid imagination, if he made such a statement as between *C. illudens* and *Canth. cibarius*. All the colored figures I have seen show that there is a very distinct color difference between *C. olearia* and *C. illudens*. In his description, nevertheless, Konrad says the pileus and stem are "brun-orangé à jaune orangé," which indicates deeper colors than most of the *icones* of the plant. It is "phosporescent." The spores of *C. illudens* are globose, 4–5 μ in diameter; those of *C. olearia* are described by Konrad as being "globuleuses-ovoides, 5–7 × 5–6 μ." His plants were collected in the region of Neuchâtel, in the Jura Mountains. In America *C. illudens* pushes much farther north than does the European species.

Doubtless these two species had the same ancestry, but to force the identity of these species of today, while scores of new forms of Agarics are being differentiated and described on far less grounds, seems to me like trying to turn back the calendar.

C. infumata, (Bres.), comb. nov. (*C. ectypa* Fr. var. *infumata* Bres. *Fungh. Trid.*, 2: 49, 1898) (see No. 22 of Synopsis). — This species is well characterized in the description given by Bresadola (*l. c*). In this instance, however, that eminent mycol-

ogist seems to have misinterpreted the Friesian species, *C. ectypa*, to which he attaches his plant as a variety. Fries' description of *C. ectypa* (see *Monographia*) clearly applies to *C. tabescens* (Scop.) Bres., which is a quite different plant. *C. tabescens* (= *C. monodelpha* Morg.) does not belong to the group of species in which the flesh of the plants turns blackish on bruising, and specifically there are many divergent characters in the two. It is therefore necessary to raise the variety " infumata" to specific rank.

C. LEPTOLOMA Pk. (see No. 90 of Synopsis) is a species which is little known; it apparently was not well known to Peck himself. In the original description he says the pileus is "hygrophanous," but omits this character in his monograph. Since the specimens grow on logs and the stems are often eccentric, one easily surmises that it is a Pleurotus. A comparison of the characters of *Pleurotus elongatipes* Pk. and of *C. leptoloma* brings me to suspect that the latter may be a dwarfed condition of the former, although there are some discrepancies which must first be cleared up.

C. OVERHOLTZII Murr. differs only from *C. cerussata* Fr. (in sense of *Monographia*) by its reported disagreeable odor and taste and the average larger size of the plant. Whether we could refer it to *C. piceina* is not sufficiently clear from the description. Murrill's species, however, was found in Colorado, where *C. piceina* occurs.

C. PICEINA Pk. (see No. 5 of Synopsis). — Kühner (17) has recently attempted to show the identity of this American species with a European species, *Clitocybe paradoxa* Const. and Duf. (= *Leucopaxillus paradoxa* (C. and D. Bours.). The latter has tuberculate spores, however, whereas the spores of *C. piceina* are smooth under high magnifications; there are other discrepancies also. *C. piceina* cannot be reduced to synonomy in this connection. Nevertheless, *C. piceina* is not at all times easily determinable in the field. There are, in this country, several close relatives, not as yet definitely clear to me. One of these may be *C. paradoxa*, but I have no experience, to date, with a rough-spored Clitocybe of this type. Then there is *C. gigantea*,

whose sporadic appearance has left it in a somewhat unstable position. *C. candida* should be recognizable to those who have access to critical notes on it. There may still be another species, especially in the western mountains, whose identity has hitherto bewildered me. Further microscopical observations and the changing color characteristics if found as a constant tendency when certain species age or when dried, may help further to differentiate these large white, mostly cespitose species.

Clitocybe pithyophila Fr. (see No. 55 of Synopsis). — This species is combined with *C. phyllophila* by Ricken (25). Rea (24), however, gives it an individual status and keeps the distinguishing character of "very crowded" gills which Fries assigned to it. He also gives us the spore characters. With the conception of it as given by Rea, the recently described American species, *C. subconnexa* Murr., coincides. Both *C. phyllophila* and *C. pithyophila* are medium-sized plants, with the pileus 3–7 cm. broad (see comments on *C. fraterna*, nom. nov.). It is a late autumn species of the pine forests in the mountains. Peck (23 *g*) reports it from the Catskill Mountains, New York.

Clitocybe tabescens (Scop.) Bres. (see No. 28 of Synopsis). — Under this name Morgan's American species, *C. monodelpha*, has finally come to rest — let us hope — in peace. There are still amateurish workers, who get a reaction out of suspecting that *C. tabescens* may after all be only a form of *Armillaria mellea*, and perchance a few who try to blow the breath of life into the long buried corpse of *Clitocybe parasitica* Wilcox, in order to show that it was either *C. tabescens* or *Armillaria mellea* or a genuine species. Also, out of all proportion to its importance is the worry over the variety *exannulata* of *A. mellea*, as originally given by Dr. Peck. From my experiences in the field, I know that *Armillaria mellea* may, under famished conditions of growth, either from lack of food or water, or possibly from other attending causes, develop whole clusters of exannulate plants; this happens in the midst of very abundant clusters of normal plants when this species suddenly appears in an area. I think, therefore, that Dr. Peck was right in the first place, and that this ecological variety is not a part of, or synonymous with, *C. ta-*

bescens. Apparently Dr. Peck allowed his better judgement to be influenced by others, for, in his monograph, written late in life, he says, "*Armillaria mellea* var. *exannulata* evidently belongs here," referring to *Clitocybe monadelpha*. Murrill (19) has followed him, presumably on the basis of this remark, placing both this variety and *C. parasitica* Wilcox under his *Monadelphus caespitosus* (Berk.) Murr., which name in turn is derived from the older *Lentinus caespitosus* Berk.

If, however, we follow Bresadola and carry the synonymy back to the bitter end, by the laws of priority, we find that Scopoli, in 1772, started the game, followed in chronological order by Bulliard with his *Agaricus gymnopodius*, Fries with his *Clitocybe ectypa*, Berkeley with *Lentinus caespitosus*, and Morgan with *Clitocybe monadelpha;* to this can be added Murrill's name for it, mentioned above. By giving paramount credit to the one who first established the microscopical data, which are the modern checks against all species of the Agaricaceae, then the name recognized by Bresadola takes proper precedence.

This species, both in Europe and America, is most abundant southward and often parasitic.

Synonyms and Excluded or Doubtful Species

C. absinthiata Batsch–Ricken. Little known.

C. albicastanea Murrill is *Hygrophorus eburneus* Fr., according to its author.

C. alboides Pk. is omitted in Peck's monograph; it is made a synonym of *C. albissima* Pk. by Murrill.

C. albo-umbilicata Murrill is *C. candicans* Fr., according to its author.

C. alutacea Cke. & Massee occurs in England.

C. ampla Fr. is *Tricholoma ampla* according to European authors.

C. aquatica Banning & Pk. is *C. tabescens* (Scop.) Bres.

C. basidiosa Pk. is *Hygrophorus basidiosus* Pk., according to Peck.

"*Tricholoma bicolor*" Murrill is very probably *C. amara* Fr.

C. Broadwayi Murrill is a tropical species, from the West Indies.

C. caespitosa Pk. has remained unrecognizable.

C. candens Murrill is *C. candicans* Fr.

C. centralis Pk. is *C. albidula* Pk.; at least a form of it (see Synopsis, No. 161).

C. cerussata Ricken is *C. nobilis* Pk.

C. chrysocephala Sacc. is *Hygrophorus auratocephalus* Ellis.

C. columbiana (Mont.) Sacc., described from the United States, is no longer recognized.

C. connexa Pk. is *C. trogii* Fr. per Peck, but more likely a form of *C. odora* Fr.

C. comitalis Fr. should perhaps be considered a small form of *C. clavipes* Fr.

C. cornucopiae Paul is *Pleurotus ulmarius* Fr.

C. cryptorum B. & Br. seems to be known only in Britain.

C. curtipes Fr. is little known.

C. cyanophaea Fr. Little is known about this species.

C. dicolor Murrill is *C. metachroa* Fr., as shown in Murrill's synonymy.

C. difformis (Schum.) Gill. is a form of *C. cerussata* Fr., according to European authors.

C. difformis Pers.–Rick. seems close to *C. brumalis* Fr.

C. Earlei Murrill is possibly a Collybia.

C. ectypa Fr. (*Monographia*) is without doubt *C. tabescens* (Scop.) Bres., although the figures in Fries' *Icones* may refer to something else (see comments).

C. erubescens (Mont.) Sacc., described from the United States, is no longer recognizable.

C. gangraenosa Fr. is poorly known.

C. Gerardiana Pk. is *Omphalia Gerardiana* Pk.

C. grumata (Scop.) Fr. seems to be rare and little known. Fries saw it in Sweden; Ricken in Germany.

C. hebepodia Fr., from Italy, is *C. connata* Bres.

C. hiemalis Murr. is Murrill's name for *C. brumalis* Fr.

C. Hoffmani Pk. was discarded by Peck. It is said to be *Omphalia chrysophylla* Fr.

C. humosa Fr. is *C. conglobata* (Vitt.) Bres.

C. hypnorum (Broud.) Rea seems to be unknown outside England.

C. incrustata Murr. is tropical (Jamaica).

C. lactariiformis Murr. is a form of *C. vibecina* Fr.

C. maculosa Pk. is probably *C. gilvaoides*, sp. nov. (see No. 68 of Synopsis).

C. marginata Pk., from Maine, is incompletely described.

C. megalospora Clements is *Collybia radicata* Fr., according to Murrill.

C. mexicana Murr. is a tropical species.

C. microspora Pk. from California is said to have a "subcartilaginous" stem, and is probably an Omphalia.

C. molybdina Fr. is a Tricholoma per Rea.

C. monadelpha Morg. is *C. tabescens* (Scop.) Bres.

C. monstrosa (Sow.) Gill. is little known and probably is a form of some known species.

C. multiformis Schaeff. is an outlawed name and the plant is *C. conglobata* (Vitt.) Bres.

C. murinifolia Murr. is too close to *C. parilis* Fr.–Ricken.

C. nigropunctata Secr.-Rick. Not much known about it.

C. nimbata Fr. is apparently not known to modern mycologists. *Tricholoma paneolum* Fr. is suggested.

C. niveicolor Murr. is described from Mexico.

C. occulta Cke. is little known.

C. obscurata Cke. is little known.

C. olearia (DC.) Fr. is southern European, known in France and Italy. Some think *C. illudens* (Schw.) Sacc. is the same. See comments.

C. olorina Fr. seems to be unknown at present.

C. opaca Fr. is apparently known only in England.

C. parasitica Wilcox was never understood by mycologists, and should be deleted from the literature.

C. patuloides Pk. is in all probability *C. amara* Fr. It is made a synonym of *C. albissima* Pk. by Murrill and placed under Melanoleuca.

C. pergamena Cke. is recognized only in Britain.

C. pescaprae Fr. is *C. conglobata* (Vitt.) Bres.

C. piniaria (Bosc.) Sacc. was originally described from South Carolina; unknown since then.

C. polia Fr. is little known; perhaps it is a Paxillus.

C. porphyrella (B. & C.) Sacc. was originally described from Connecticut; unknown since then.

C. pruinosa Lovejoy (*non* Fries); one of the "cyathiformis" group, but which one is hard to say.

C. puellula Karsten is *C. verrucipes* (Fr.) Maire, according to Maire and Bresadola.

C. pusilla Pk., from California, on manure. The description is insufficient.

C. radiozonaria (Johns.) Sacc. from Minnesota. The description is insufficient and no type specimens exist.

C. rancidula Banning is apparently *Tricholoma paneolum* var. *cespitosa* Bres.

C. setiseda (Schw.) Sacc., described from North Carolina, is unknown since then.

C. stipitata Murr. is apparently described from dried specimens. Unrecognizable.

C. subconnexa Murr. is probably *C. pithyophila* Fr.

C. subdecastes Cke. & Massee is not known outside England.

C. subditopoda Pk. is merely a pale form of *C. ditopoda* Fr.

C. subinversa Murr. The description is insufficient.

C. subinvoluta W. G. Smith is a Paxillus, according to Rea.

C. subinvoluta Batsch is *C. gilva* Fr.

C. submarmorea Murr. is *C. marmorea* Pk.

C. subsquamata Murr. This name is used by Murrill for *C. squamulosa* (Pers.) Quél.

C. subzonalis Pk. is *C. gilva* Fr. according to Peck, therefore probably *C. gilvaoides*, sp. nov. Kauff.

C. sulphurea Pk. is undoubtedly *Pleurotus sulphuroides* Pk.

C. tarda Pk. is considered by Murrill to be *Tricholoma sordidum* Fr.

C. tenebricosa Murr. Growing and developing in the dark. It looks more like a Collybia according to its appearance on the photograph (*Mycologia* 7: 275, 1915. Plate 165).

C. testaceoflava Murr. is tropical (Jamaica).

C. Trogii Fr. is probably *C. subalutacea* Fr. (*non* Batsch).

C. trojana Murr. is tropical (Jamaica).

C. trullaeformis Fr. is little known.

C. tumulosa (Kalchbr.) Fr. is *C. conglobata* (Vitt.) Bres.

C. tyrianthina Fr. is not known by mycologists.

C. violaceifolia Murr. According to the description this has adnexed gills, grows on wood, and the gills are violet. Scarcely a Clitocybe.

C. virens Scop. is *C. odora* Fr.

C. xanthophylla Bres. is *Omphalia Bresadolae* Maire.

C. zygophylla Cke. & Massee is little known.

University of Michigan

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PLATE VIII

CLITOCYBE AMARA

PLATE IX

CLITOCYBE ATRIALBA

CLITOCYBE DIATRETA var. FUSCESCENTIPES

PLATE XI

CLITOCYBE GILVAOIDES

CLITOCYBE RIVULOSA var. ANGUSTIFOLIA

Clitocybe vermicularis forma cystidiosa

CLITOCYBE GALLINACEA

CULTURAL LIFE-HISTORIES OF DIAPORTHE III*

LEWIS E. WEHMEYER

OF THE four species of Diaporthe considered in the following pages, one, *Diaporthe oxyspora* (Pk.) Sacc., can be considered as typical, having the marginal zones within the substratum, and the Phomopsis stage in its life-history, which are characteristic of this genus. The second, *Diaporthe tessella* (Pers.) Rehm, is a typical Diaporthe as far as the perithecial stroma is concerned and deviates only in the fact that but one type of conidium has so far been observed in cultures of this species. The third, *Diaporthe Wibbei* Nit. var. **comptoniae** (E. & E.), comb. nov., shows no marginal zones within the substratum, produces septate-appendaged conidia and shows affinities with the Pseudovalsa group considered by the writer in a previous paper (36). The fourth, *Diaporthe phomaspora* (Cke. & Ell.) E. & E., has the typical unequally two-celled ascospores and the Phoma-like imperfect stage of the genus Apioporthe and is placed in that genus.

Diaporthe Wibbei Nit. var. **comptoniae** (E. & E.), comb. nov.

The seven species of Diaporthe described upon Myrica have been greatly confused in the past. A study of the exsiccati of these seven species reveals three good species and one variety.

In 1867 Nitschke (23, pp. 262 and 305) described *Diaporthe valida* and *Diaporthe Wibbei* on Myrica. He described both these species as having an effuse stroma circumscribed by a dark zone. All the exsiccati examined, on the contrary, showed no dark zones

* The work reported in this paper was carried out at Harvard University under the grant of a National Research Fellowship in the Biological Sciences.

in the substratum, and were typical of what is here considered as *D. Wibbei*. Through the kindness of Dr. E. Hannig of the Botanisches Institute of Münster, the writer has been able to examine Nitschke's original material of these two species. *D. valida* shows a definite blackened ventral zone within the wood, and is a form of *D. eres* Nit. on Myrica. The original material of *D. Wibbei* (from Wibbe, Feb., 1868) shows such zones within the wood on one twig, but no fruit bodies are present except a Cytospora-like imperfect stage. The note on this specimen gives no spore measurements. The two later collections cited by Nitschke (from Beckhaus, March and May, 1868) lack any blackened zones in the substratum, have slightly inequilateral ascospores 15–16 × 3–4 μ and are typical of the later exsiccati of this species.

Diaporthe prominula Sacc. Bomm. & Rouss., as represented by Rehm's Ascom. No. 1023, is the same as *D. Wibbei* (as represented by the material from Beckhaus). The original description of *D. prominula* (3, p. 197) gives the spores as curved and ciliated at one end. House (19, p. 31) also mentions such appendages on a specimen of what he calls *D. phomaspora* (C. & E.) Sacc. These references to appendages on the ascospores are undoubtedly due to a confusion of the conidia, which are so appendaged, with the ascospores.

The *Sphaeria Aubertii* of Westendorp (38, p. 15), placed in the genus Diaporthe as *D. Aubertii* (West.) by Lambotte (22, p. 383), is probably this same species although no authentic material has been seen by the writer.

There is a distinct variety of *D. Wibbei* occurring on *Myrica asplenifolia* L. All the specimens examined on this host show ascospores somewhat shorter (9.5–12 × 4–5 μ) and more strongly curved than those of specimens on other species of Myrica. This variety was described by Ellis (10, p. 234) in 1890 as *Diaporthe comptoniae*, and *Sphaeria comptoniae* Schw. was given as a probable synonym. In 1900 Hennings (15, p. 37) described a var. *berolinensis* of *D. comptoniae* on *Myrica asplenifolia* with spores 16–19 × 4.5–5 μ. His description seems to be that of *D. Wibbei*, but the writer has seen no material of this variety.

The third species on Myrica is in reality an Apioporthe, as its ascospores are normally unequally two-celled. This species was first described by Cooke and Ellis (6, p. 10) as *Valsa phomaspora*, and was later placed in the genus Diaporthe by Ellis (11, p. 437). Ellis' N. A. F., No. 179, of this species, is identical with the material used as a source of the writer's cultures.

Diaporthe tecta (Cke.) Sacc. is rather difficult to place, but is probably the same as *D. phomaspora*. The original description by Cooke (4, p. 109), based on Ravenel's Fung. Am., No. 747, gives the spores as 18 × 5 μ. Ellis (11, p. 426) redescribed this species from the same material and gave the spores as slightly curved and 6–7 × 1.5–2 μ. The writer's examination of Ravenel's No. 747, in the Farlow Herbarium, yielded only decayed pustules from which most of the perithecia had fallen out. Only a few, small, oval, one-celled conidia were found. These were similar to, but smaller than, those obtained in cultures of **Apioporthe phomaspora** (Cke. & Ell.), comb. nov. A very few spores with a faint eccentrically placed septum were seen, and the general structure of the stroma seemed to be that of *A. phomaspora*.

Material of *Diaporthe Wibbei* Nit. var. **comptoniae,** comb. nov., was collected near Medford, Mass., on *Myrica asplenifolia* L. The fungus appears on the surface of the twigs as numerous, small, papillate pustules, through which the short stout ostioles are scarcely and tardily erumpent. The perithecia are 240–440 μ in diameter, and lie singly or in small clusters in the upper bark. There is usually a development of light colored entostromatic mycelium about the perithecia (Pl. XV, Fig. 1), but there are no blackened zones within the substratum. The asci (Pl. XVI, Fig. 4) are 40–50 × 8–11 μ. The spores (Pl. XVI, Fig. 3) are biseriate in the ascus, fusoid-elliptic, two-celled, hyaline, constricted at the septum, somewhat curved or bent, and measure 9–13.5 × 3.5–5 μ.

Ascospores from this material were sprayed on agar on September 14, 1926. The following day these spores were germinating (Pl. XVI, Fig. 2), usually by means of a single germ tube which was narrower (2.7 μ) at the point of emergence from the spore than at its normal thickness (4 μ).

Single-spore and single-ascus cultures on oatmeal agar produced a slight superficial weft of white cottony hyphae. Within two to three weeks, numerous compacted stromatic areas arose either in this superficial weft or partly immersed in the agar. The conidia (Pl. XVI, Fig. 5) produced in these stromata were fusoid-elliptic, more or less inequilateral or curved, two-celled, hyaline, 8–15 × 2.5–4 μ, and had a flagellate apical appendage which was up to 45 μ in length and 0.5–0.7 μ in diameter. The conidia were exuded in blackish masses.

The stromatic tissue which is about to give rise to conidia is composed of actively growing thin-walled hyphae which are 2–3 μ in diameter, and rich in protoplasm. Loose ends of these hyphae, which take a bright stain with eosin, appear at one or a number of points within the stroma, and conidia are rapidly cut off from these hyphal tips until a central spherical or irregularly shaped cavity, with a peripheral hymenial layer of conidiophores, results. There is a subhymenium consisting of one or several layers of hyphae with a dense protoplasmic content, which act as a nurse tissue to the conidiophores (Pl. XVI, Fig. 6). The extent of the cavity is limited by the thickening and browning of the walls of the outer layers of stromatic hyphae. The cavities may become widely exposed on the surface, but are more often deep seated and entirely enclosed. As each conidium is formed its connection with the conidiophore becomes constricted and elongated (Pl. XVI, Fig. 6 *b*). The conidium is cut off from the conidiophore at the apex of this elongated tip or stalk (Pl. XVI, Fig. 6 *a*). The succeeding conidium arises by the formation of a constriction somewhat back from the apex of the conidiophore (Pl. XVI, Fig. 6 *c*). The growth of the portion of the conidiophore above this constriction gives rise to the spore (Pl. XVI, Fig. 6 *d*), while the elongation of the stalk of the previous conidium forms the apical appendage (Pl. XVI, Fig. 6 *e*).

On September 21, steam-sterilized twigs of *Myrica asplenifolia* were inoculated from single-spore cultures. These first cultures produced only sterile ectostromata. Later twig cultures, made on October 26, produced numerous erumpent conidial stromata, 0.3–0.8 mm. in diameter. These conidial ectostromata on twigs

arise as a cushion of upright, parallel, septate hyphae (2–7 μ in diameter), which rupture the periderm by the pressure of their upward growth. The conidial cavities which arise within these stromata are at times widely exposed to the exterior, but usually remain as definitely enclosed locules.

This conidial stage has been described by Ellis (9, p. 156) as *Pestalozzia flagellifera* E. & E., and was given by Saccardo (32, v. 10, p. 476) as *Barclayella* (*Neobarclaya*) *flagellifera* (E. & E.) Sacc. This imperfect stage is of particular interest as it presents sepate-appendaged conidia, which have hitherto been unknown in the genus Diaporthe. The black color of the conidia, in mass, is also atypical.

In a previous paper, the writer (36, p. 619) has pointed out that septate conidia in the Diaporthaceae are characteristic of a line of development culminating in the genus Pseudovalsa, and that certain species of Diaporthe lacking the typical blackened zones in the substratum might possess hyaline septate conidia and represent the simpler forms in this line of development. Accurate cultural data as to conidial connections are still wofully lacking, but this connection does at least show that there are such simple forms with septate conidia, and which show a relationship to the Pseudovalsa group.

A consideration of the perithecial stroma of *D. Wibbei* var. *comptoniae* brings to view the fact that the lack of any ectostroma, and the visible development of entostromatic hyphae about the perithecia, as well as the lack of blackened zones, relate this species definitely to the simpler forms of the Pseudovalsa type.

Apioporthe phomaspora (Cke. & Ell.), comb. nov.

The genus Apioporthe was erected by Von Höhnel (16, p. 381) for the *Diatrype anomala* of Peck (24, p. 76), which has a strongly developed Diatrype-like stroma and unequally two-celled spores. The writer (35, p. 246) has previously pointed out that *Diaporthe obscura* (Pk.) Sacc., on Rubus, should belong in the genus Apioporthe as **A. obscura** (Pk.), comb. nov. *A. obscura* has a well-developed stroma about the perithecia, but this stroma is not so

strongly erumpent as in *A. anomala.* In *Apioporthe phomaspora* this entostromatic development shows a still greater reduction, there being only a slight development of mycelium about the perithecia, and a slight blackening of the bark surface above them.

Material of *Apioporthe phomaspora* was collected near Wolfville, Nova Scotia, on twigs of *Myrica carolinensis* Mill. It appears superficially like *Diaporthe Wibbei,* except that the pustules average slightly larger and usually break open by an elongated rupture of the periderm (Pl. XV, Fig. 2). The perithecia are 200–360 μ in diameter, have slender necks and are clustered beneath a blackened portion of the bark surface. There are no blackened zones within the bark. The asci (Pl. XVI, Fig. 9) are clavate and measure 43–46 $\times$ 8–9 μ. The spores (Pl. XVI, Fig. 10) are biseriate in the ascus, hyaline, elliptical, narrowed toward one end, unequally two-celled and measure 8–11 $\times$ 2.5–4 μ. The smaller cell sometimes becomes enlarged to the size of the second cell.

The first attempt to germinate ascospores from this material failed, probably because of their immaturity. The twigs were then placed in a damp chamber for two days, and a second spray of ascospores made on July 29, 1926. These spores germinated within twenty-four hours by means of a single germ tube, 2.5–3 μ in diameter, from the larger cell. The germinating spores were 11–12 $\times$ 3.5–4 μ.

Single-spore cultures on oat agar produced numerous irregularly pulvinate stromata, some of which remained sterile, while others exuded yellowish spore horns of fusoid-elliptic, hyaline, one-celled conidia (Pl. XVI, Fig. 7), which were often inequilateral or slightly curved, and measured 6.5–10 $\times$ 2.5–3.5 (4) μ. These stromata were composed of loosely compacted hyphae, and when conidial production took place the actively growing hyphae merely broke up into numerous conidia, while those hyphae which had formed thickened walls and become inactive, remained as a more or less complete wall-like tissue surrounding the central cavity resulting from spore formation.

Steam-sterilized twigs of *Myrica asplenifolia* L., inoculated

from single-spore cultures on September 13, produced only sterile, erumpent-superficial ectostromata composed of broad, upright, parallel, septate, greenish-black hyphae (Pl. XVI, Fig. 8). Similar inoculations made on December 2 resulted in an indefinite type of conidial production. One of these twigs showed numerous, minute, white, granular masses, some 20–100 μ in diameter, upon its surface. These proved to be masses of conidia identical with those produced in agar cultures. The bark tissues of these twigs were penetrated by a nutritive mycelium. At various indefinite points, often deep within the bark, this mycelium increased in amount to form irregularly shaped, or effuse stromatic masses. In these areas (Pl. XVI, Fig. 8) conidia were produced, as on agar, by the breaking up of the mycelium. In some, large spherical stromatic masses were formed resulting in a pycnidial structure, but in most the conidia were formed loosely in these irregular pockets within the bark. Only one type of conidium was produced.

This species with its slight stromatic development in both the perithecial and conidial stage is the most primitive of the genus. The imperfect stage of *A. obscura*, which has been obtained in culture by the writer (35, p. 245), is similar to that of *A. phomaspora* except for the greater stromatic development, which is also true of the perfect stage. *A. anomala* shows the greatest stromatic development, but its imperfect stage is so far unknown.

Diaporthe oxyspora (Pk.) Sacc.

The twelve species of Diaporthe described on Ilex and Magnolia resolve themselves into five, or perhaps six, species.

The *Valsa oxyspora* described by Peck (24, p. 73) in 1876 was placed in the genus Diaporthe by Saccardo (32, v. 1, p. 627) in 1882. Both Dearness (7, p. 348) and House (20, p. 38) have pointed out that the appendages of *D. oxyspora* (Pk.) Sacc. are very evanescent, and that *D. epimicta* E. & E. and *D. ocularia* (Cke. & Ell.) Sacc. are synonyms of this species. The type of *D. epimicta* was first given out as *Diatrype Badhami* Curr.[1]

[1] Rab., Fung. Eur., No. 3154 of *Diaporthe Badhami* (Curr.) Sacc., which Winter remarks does not fit Currey's description, is *D. oxyspora* on *Ilex verticillata*.

(N. A. F., No. 495), but was later described by Ellis (11, p. 439) as a Diaporthe. This type is undoubtedly the same as the type of *D. oxyspora* (Herb. N. Y. St. Mus., Sandlake, 1874, by Peck), although the spores are immature (12 × 3–4 μ), which may account for Ellis' small measurements (12 × 8 μ). No specimens of *D. ocularia* have been seen by the writer, but the description is that of the occurrence of *D. oxyspora* on *Ilex glabra* (L.) Gray. The form on this host was described by Ellis (8, p. 99) as *Valsa cercophora*, and was transferred to the genus Diaporthe by Saccardo (32, v. 2, Add. p. 49). On *Ilex glabra* the periderm is closely adherent about the ostioles and not thrown back widely as on *Ilex verticillata* (L.) Gray, and there is a complete ventral zone within the wood. If these characters are constant on this host, this would constitute a variety on *Ilex glabra*.

Diaporthe crustosa Sacc. & Roum., described (31, p. 43) on *Ilex aquifolium* (Tourn.) Adans., is *Diaporthe eres* Nit., or a form of this species on Ilex. The type material (Roum., Fung. Gall., No. 1562) of this species, in the Farlow Herbarium, is a mere fragment, but is typical of *D. eres*. Feltgen (12, p. 145) gives *D. crustosa* as similar to *D. rhoina* Feltg., which is *D. eres* on Rhus.

Diaporthe americana was described by Spegazzini (33, p. 457) as an effuse form on Magnolia, but no spores were seen or described. Peck (25, p. 29) gave the spores of this species as 15–17.5 × 4 μ, which agrees very well with a specimen in the New York State Museum collected by Peck at Carrolton, New York. In 1890, Ellis (10, p. 235) again described *D. americana*, and gave the spores as 10–12 × 3 μ. The material which served as a basis for this description was later described (11, p. 433) as *Diaporthe magnoliae* E. & E. This original material of Ellis' (Newfield, New Jersey, 1889) shows a typical specimen of *D. eres* on Magnolia, with spores 12–13 × 2.5–3.5 μ. *D. crustosa* and *D. magnoliae*, therefore, are merely forms of *D. eres* at the most.

Diaporthe ilicina Cke. (5, p. 74) is a similar effuse species with somewhat longer spores (12–15 × 2.5–3.5 μ) and a lateral blackened zone which is visible through the periderm as a line delimiting the entostromatic areas.

Diaporthe binoculata (Ell.) Sacc. was described as *Valsa binoculata* by Ellis (8, p. 111), and placed in the genus Diaporthe by Saccardo (32, v. 9, p. 708). This is a typical species with very broad ascospores. Ellis' var. *ilicis* (N. A. F., No. 2746) of this species, on *Ilex verticillata* differs from *D. binoculata* in the well-developed ectostroma and the lack of any ventral zone, and is in reality distinct enough for a separate species. Peck's (25, p. 28) var. *magnoliae-acuminatae* is the same as *D. binoculata*. The forma *ilicis* Rehm (30, p. 58) (Rehm, Asc., No. 1972) is the var. *ilicis* of Ellis. The var. *clethrae* of Dearness (*Myc.*, 16, p. 158) has not been seen by the writer.

Specimens of *Diaporthe yerbae* Speg. and *D. mate* Speg., on *Ilex paraguayensis* Hook., have not been seen, but *D. mate* (34, p. 122) is given as resembling *D. binoculata*, and *D. yerbae* (34, p. 122) as having spore and ascus measurements identical with those of *D. eres*, so they are probably very similar to these two species.

Material of *Diaporthe oxyspora* (Pk.) Sacc. was collected near Wolfville, Nova Scotia, on *Ilex verticillata* (L.) Gray. It appears on the surface of the twigs as broad, circular or elongated, blackened discs, erumpent through wide angular ruptures of the periderm. The perithecia are 400–520 μ in diameter, and clustered in isolate entostromatic areas outlined by a narrow, dorsal, blackened zone, which is usually incomplete or absent in the wood beneath (Pl. XV, Fig. 3). The asci (Pl. XVII, Fig. 3) are clavate, and measure 54–60 $\times$ 6–7 μ. The spores (Pl. XVII, Fig. 2) are biseriate in the ascus, long-fusoid, two-celled, hyaline, constricted at the septum, and have an evanescent bristle-like appendage at each end. The spores measure 12.5–16 $\times$ 2.5–4 μ.

The first attempts to germinate spores from this material, on July 22, 1926, failed. The twigs were then placed in a damp chamber until July 26, when a second spray of ascospores was made on agar. These spores germinated within twenty-four hours by means of a single-germ tube, 2.5–3 μ in diameter. The germinating spores measured 16.5–18 $\times$ 4–5 μ.

Single ascus cultures on oatmeal agar produced small hemispherical pycnidial stromata which contained variously shaped,

centrally placed locules. These locules were lined within by a layer of long cylindrical conidiophores, and bounded without by a wall-like zone of slightly differentiated hyphae. Only one type of conidium was found in agar cultures. This was of the alpha type (Pl. XVII, Fig. 4) and was fusoid-elliptic, one-celled, hyaline, and measured 8–13 × 2.5–3.5 μ.

Steam-sterilized twigs of *Ilex verticillata* inoculated from both single-spore and single-ascus cultures produced numerous erumpent stromata, within many of which pycnidial locules were formed (Pl. XVII, Fig. 1). These stromata arise as proliferations of mycelium within isolated areas of the upper bark, which soon become bounded by a zone of blackened tissue. This zone never pentrates deeply into the wood nor forms a ventral zone. The growth of stromatic mycelium is particularly rapid on the bark surface, where it forms an ectostromatic cushion which ruptures the periderm and becomes the widely erumpent disc. When pycnidial locules are formed, they originate in the upper portion of this ectostroma before it ruptures the periderm. The locules are flattened or irregular, and contain, besides the alpha type of conidium already described, a second beta type (Pl. XVII, Fig. 5) which is cylindrical, straight or slightly allantoid, one-celled, hyaline, and measures 8 9 × 1.3–1.5 μ. The spore horns containing the beta type of conidia are white to pinkish, while those with the alpha type predominantly present are flesh color to yellow. Perithecial initials were also produced on twigs in culture, and usually arose within the entostromatic areas of the bark, or occasionally in the superficial ectostroma.

Diaporthe tessella (Pers.) Rehm

Diaporthe tessella (Pers.) Rehm was collected at Whitmore Lake, Michigan, on twigs of *Salix sp.* The fungus appears on the surface of the twig as clusters of separately erumpent papillate ostioles, which are usually grouped about a central, blackened, ectostromatic disc, 0.2–0.4 mm. in diameter. The entostromatic areas (Pl. XV, Fig. 4) are isolate or confluent, each containing two to eight perithecia 400–725 μ in diameter. There is no blackening of the bark surface, but a dark marginal zone dips

from the periderm to the wood surface. This marginal zone is usually visible through the periderm as a circumscribing line about each perithecial cluster. The asci (Pl. XVII, Fig. 9) are clavate and measure 110–145 × 18–21 μ. The spores (Pl. XVII, Fig. 8) are cylindric-fusoid, usually curved or bent at the septum, two-celled, hyaline, constricted at the septum, 35–55 × 7–9 μ, and often possess a short hyaline appendage at each end.

Diaporthe tessella was first described by Persoon (26, p. 48), as *Sphaeria tessella*. He described it as having distant ostioles and a circumscribing line. Fries (14, p. 411) listed it as *Valsa tessella* (P.). It was first given as *Diaporthe tessella* in 1873, in Rehm's Asc., No. 167. Karsten (21, p. 79) described it as *Cryptospora tessella* (P.) in 1873. He gave the spores as being appendiculate and 40–70 × 8–10 μ. His specimen (Fung. Fenn., No. 985) is typical of *D. tessella*. The spores show evidences of appendages and are 37–50 × 7.5–9 μ. In 1876, Peck (24, p. 74) described this species as *Valsa mucronata*. The type collection of *V. mucronata* (Herb. N. Y. St. Mus., Sandlake, 1874) is typical of *D. tessella*. This species was again described, as *Valse glyptica* B. & C., by Berkeley (2, p. 100) in 1876. Both *V. glyptica* and *V. mucronata* were placed in the genus Diaporthe by Saccardo (32, v. 1, p. 629). Von Höhnel (17, p. 122) gives both these species as synonyms of *D. tessella*. In 1890, Ellis (10, p. 236) described *Melanconis salacina* E. & E., which his type collection (N. A. F., No. 2523) proves to be *D. tessella*.

In 1921, Petrak (27, p. 289) based his new genus Allantoporthe on *D. tessella*. The distinguishing characters of this genus were the allantoid nature of the ascospores, the lack of paraphyses, and the supposed connection of the imperfect stage *Discella carbonacea* (Fr.) Berk. & Br. These ascospores are not of the truly allantoid type, but are merely slightly curved or bent at the septum, which is common to a number of species of Diaporthe. The absence of paraphyses is a poor diagnostic character to say the least, and Petrak (28, p. 182) himself revises his conidial connection. The following cultural connection shows that the imperfect stage of *D. tessella* is not a Discella, so that the genus Allantoporthe breaks down altogether.

A suspension of ascospores of this species was sprayed on agar on October 10, 1925. A few of these spores germinated within the first twenty-four hours, while others germinated during the second day. The spores which germinated were invariably those with a granular protoplasmic content, many spores with homogeneous transparent contents failing to germinate. A single germ tube 4.5 μ in diameter was produced.

Single-spore cultures on oatmeal agar produced a superficial weft of cottony mycelium, within which the pycnidial stromata arose as compacted masses of interwoven hyphae which became septate and finally produced a pseudo-parenchymatic stroma. Only one type of conidium (Pl. XVII, Fig. 7) was produced in these stromata. These conidia varied in shape from inequilateral or curved cylindric-fusoid to allantoid, were one-celled, hyaline, and measured 5.5–9 × 1–1.5 μ.

The type of conidial formation was quite variable and seemed to depend upon the physiological conditions of growth. When conidial production begins while the tissues are yet loosely compacted and prosenchymatic, and conditions still favor hyphal growth, cavities are initiated at a number of points in a manner similar to that described previously for *D. megalospora* E. & E. (37), that is, the hyphal cells become separated along a line of fission by a lysigenetic dissolution of the cell walls, and the protoplasts of the cells grow out as conidiophores from which the conidia are cut off. If conidia are not initiated until the stromatic tissue is more compacted and parenchymatic, and individual hyphal growth no longer possible, the protoplasts of the individual cells grow out as short conidiophores, which cut off conidia from their tips (Pl. XVII, Fig. 10 *a*). If the formation of conidia is still longer delayed until the cells become physiologically isolated as regards the transfer of food materials, the individual protoplasts may round up as conidia within the disintegrating cell walls (Pl. XVII, Fig. 10 *b*). This condition suggests the conidial formation attributed by Von Höhnel (18) to his section Endogenosporae of the Fungi Imperfecti. Any further delay in the formation of spores results in a sterile stroma. On agar no definite hymenium was formed. Isolated patches of conidio-

phores occurred, but the conidia were usually loosely inbedded in a gelatinous matrix of the broken down cell walls, or still enclosed within the cell wall (Pl. XVII, Fig. 10). On twigs definite conidial hymenia were formed.

Petrak (29, p. 89) in his study of endogenous spore formation found a similar wide variation in the type of spore production in *Coniothyrium olivaceum* Bon. He found spores formed sometimes within the cell wall with no conidiophore, at other times upon bud-like protrusions of the protoplast, and again upon true conidiophore hyphae. Such variation within one species should demonstrate the futility of attempting to force genera or even species into any narrow category as regards conidial formation. Yet Petrak further divides endogenous spore formation into five different types. Archer (1, p. 11) has pointed out that several of the species mentioned by Petrak do not form their spores endogenously.

It is important, therefore, that the possible range of such "physiological variations" within a species or a given group of species should be understood and appreciated, and not mistaken for specific variations, before any narrow taxonomic lines are drawn.

On November 5, two steam-sterilized twigs of Salix were inoculated from a single-ascus culture. Small ectostromata arose on the surface of the bark and produced small ruptures of the periderm. The pycnidial stromata on these twigs consisted of the fusion of such an ectostroma on the bark surface with a proliferation of entostromatic hyphae within the surface bark layers. One or more pycnidial cavities, spherical or irregular in shape, were formed, usually within the entostromatic tissue of the surface bark layers. These locules were generally, but not always, surrounded by a blackened wall-like zone, and were lined within by a layer of conidiophores bearing a single type of conidium identical with that formed on agar. In many cases a rapid proliferation of entostromatic hyphae took place throughout the bark beneath the pycnidium, and this area was then cut off by a marginal blackened zone, which can arise either before or after the formation of the pycnidium. Where such entostromatic areas

are not formed, the bark tissues and the pycnidium itself rapidly disintegrate. No perithecia were produced in culture.

SUMMARY

The cultural connections of the perfect and imperfect stages of four species of Diaporthe are given.

The imperfect stage of *Diaporthe Wibbei* Nit. var. **comptoniae** (E. & E.), comb. nov. (*D. comptoniae* E. & E.), was found to be *Neobarclaya* (*Barclayella*) *flagellifera* (E. & E.) Sacc., with two-celled appendaged conidia. These septate conidia, which are black in mass, together with certain characters of the perithecial stroma, relate this species to the simpler forms of the Pseudovalsa group. The method of development of the appendaged conidia is given.

Apioporthe phomaspora (Cke. & Ell.), comb. nov. (*Diaporthe phomaspora* Cke. & Ell.), produced a single type of fusoid-elliptic, hyaline, one-celled conidia within irregular and loosely compacted stromata.

Diaporthe oxyspora (Pk.) Sacc. produced a Phomopsis type of imperfect fruit body with two types of conidia. The beta conidia are short cylindric to allantoid.

Diaporthe tessella (Pers.) Rehm. produced a Phomopsis type of fruit body, but only one type of cylindric to allantoid conidium was formed in culture. The formation of these conidia was quite variable in culture, often being of an endogenous type.

A discussion of the synonymy of the species of Diaporthe on Myrica, and on Ilex and Magnolia, is given.

Harvard University

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EXPLANATION OF PLATES

PLATE XV

FIG. 1. Vertical section of perithecial stromata of *Diaporthe Wibbei* Nit. var. **comptoniae** (E. & E.), comb. nov., on *Myrica asplenifolia* L., showing stromatic development about the perithecia. (× 20)

FIG. 2. Vertical section of perithecial stroma of **Apioporthe phomaspora** (Cke. & Ell.), comb. nov., on *Myrica carolinensis* Mill. (× 20)

FIG. 3. Vertical section of perithecial stroma of *Diaporthe oxyspora* (Pk.) Sacc. on *Ilex verticillata* (L.) Gray. (× 20)

FIG. 4. Vertical section of perithecial stroma of *Diaporthe tessella* (Pers.) Rehm. on *Salix sp.* (× 20)

PLATE XVI

Diaporthe Wibbei Nit. var. **comptoniae** (E. & E.), comb. nov.

FIG. 1. Vertical section of pycnidial stroma as produced in culture on twigs of *Myrica asplenifolia* L.

FIG. 2. Germinating ascospore

FIG. 3. Ascospores

FIG. 4. Ascus with ascospores

FIG. 5. Conidia produced in culture

FIG. 6. Diagrammatic cross-section of hymenial layer of pycnidial cavity, showing method of spore formation

Apioporthe phomaspora (Cke. & Ell.), comb. nov.

FIG. 7. Conidia formed in culture

FIG. 8. Vertical section of twig of *Myrica asplenifolia* L., showing sterile ectostroma and type of conidial cavities formed within the bark, in culture

FIG. 9. Ascus with ascospores

FIG. 10. Ascospores

PLATE XVII

Diaporthe oxyspora (Pk.) Sacc.

FIG. 1. Vertical section of pycnidial stroma as formed on twigs of *Ilex verticillata* (L.) Gray in culture

FIG. 2. Ascospores

FIG. 3. Ascus with ascospores

FIG. 4. Alpha type of conidia produced in culture

FIG. 5. Beta type of conidia produced in culture

Diaporthe tessella (Pers.) Rehm.

FIG. 6. Vertical section of pycnidial stroma as formed in culture on twigs of *Salix sp.*

FIG. 7. Type of conidium produced in culture

FIG. 8. Ascospores

FIG. 9. Ascus with ascospores

FIG. 10. Cross-section of portion of pycnidial stroma, showing type of conidial formation found in agar cultures

PLATE XV

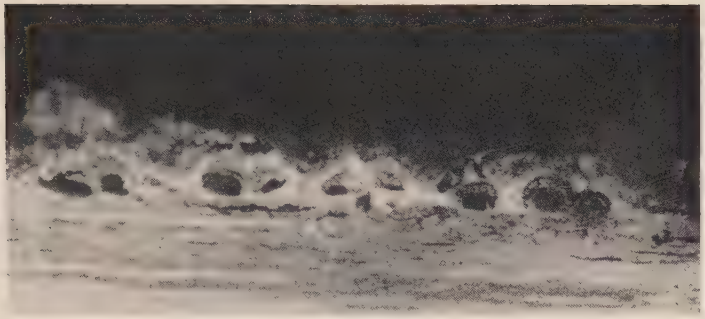


FIG. 1

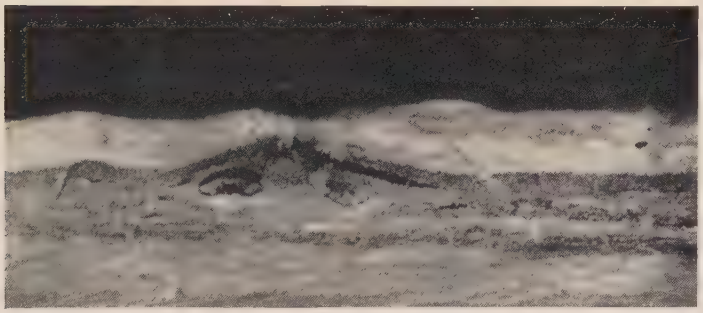


FIG. 2

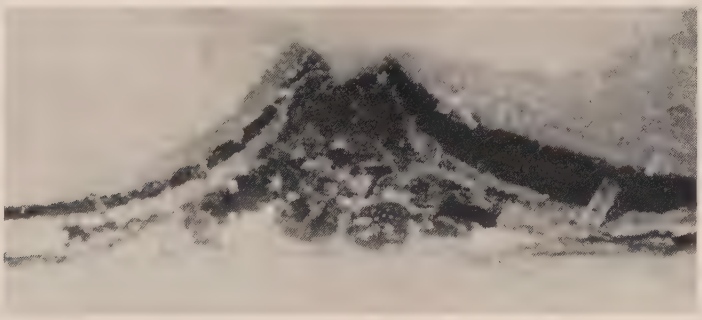


FIG. 3

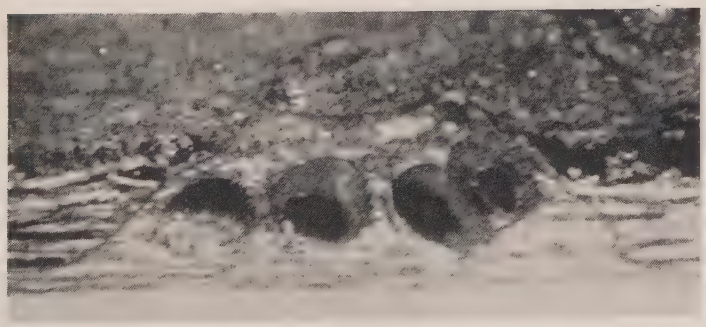
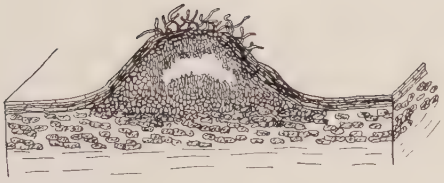


FIG. 4

PLATE XVI



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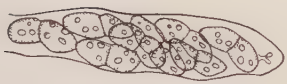

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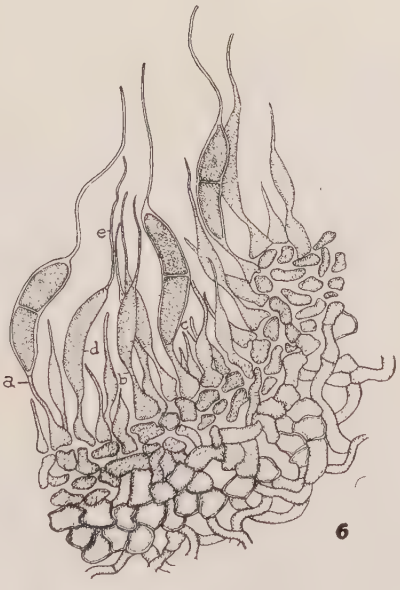

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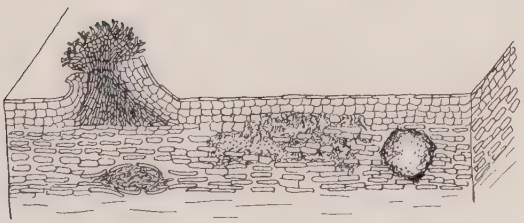

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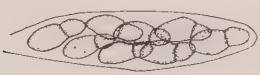

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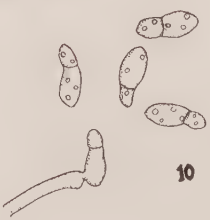

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PLATE XVII

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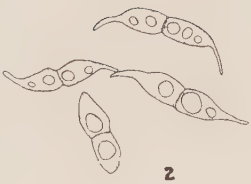

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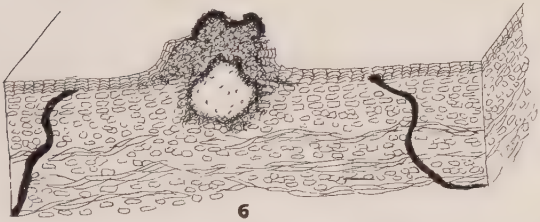

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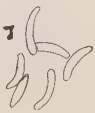

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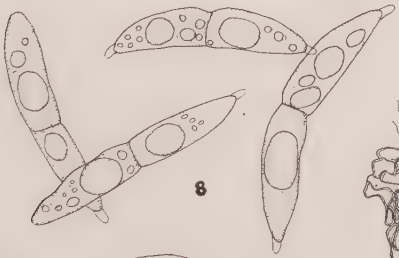

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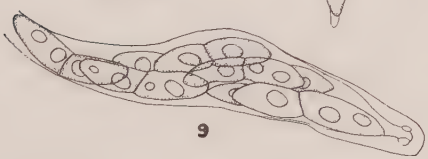

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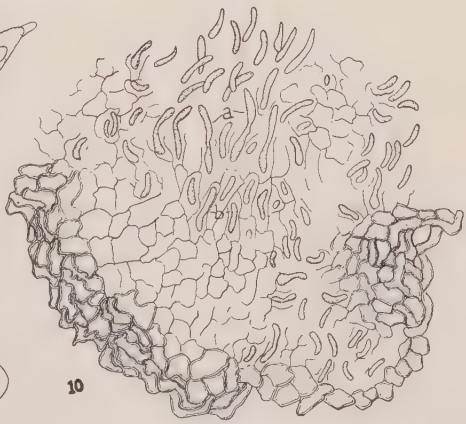

10

OBSERVATIONS ON THE MORPHOLOGY OF THE SEED OF *CERASTIUM VULGATUM*

EDWARD F. WOODCOCK

THE seeds of the plants in the Order Caryophyllales or Centrospermae of Engler and Prantl are characterized by a curved embryo which is usually surrounded by a nourishing tissue. Malligson (8) has shown by his serum diagnostic investigations that there is a very close relationship existing between the families included in this order.

The exact nature of the storage region in the mature seeds of the foregoing Order is in question among the older investigators, as is shown by the fact that Britton and Brown (3) call the storage tissue outside the embryo "endosperm," Bentham and Hooker (2) "albumen," and Harz (4) "endosperm."

Stevens (7) and the writer (9, 10) have found that the storage region in Polygonaceae consists entirely of endosperm. The writer has carried on investigations on the Phytolaccaceae (11), Portulacaceae (12) and Caryophyllaceae (13). In the first two families the storage region consists entirely of perisperm. In the species *Alsine media* L. of the Caryophyllaceae the major portion of the storage region consists of perisperm tissue densely filled with starch. In addition to the perisperm there is present about the tip of the radicle in the mature seed a cap of cellular endosperm which appears early in the development of the seed. Each cell of this cap is furnished with a large nucleus and dense cytoplasm. Perhaps this layer may have the digestive power which Johnson (5, 6) found for the Piperaceae and suggested for the Caryophyllaceae, but, considering its relatively small amount in proportion to the amount of perisperm and its position over only a portion of the embryo, it hardly seems possible that such can be its function.

Artschwager (1) has described the development of the seed in *Beta vulgaris* L. and the conditions found are quite similar in many respects to those described by the writer for the Phytolaccaceae, Portulacaceae and Caryophyllaceae. The curved embryo is common for *Beta vulgaris* L. and the families mentioned above. The starchy perisperm and endosperm-remains in the mature seed are also common. In the Phytolaccaceae the endosperm is evident as a cap of somewhat distorted vacuolated cells about the radicle of the embryo; in the Portulacaceae the entire embryo is surrounded by crushed endosperm cells; in Caryophyllaceae there is present an endosperm cap as in Phytolaccaceae but the cells are filled with dense contents; and in *Beta vulgaris* L. there is present an endosperm cap of one layer of cells having dense granular contents.

The writer feels that it might be of interest to report on a careful study of another genus of Caryophyllaceae to see to what extent the seed development differs, if at all, from that found in *Alsine media* L. This paper gives the results of a study of the seed development of *Cerastium vulgatum* L.

DESCRIPTION AND DISCUSSION OF THE MORPHOLOGY OF THE SEED

Microtome sections stained in Delafield's haematoxylin were used for a study of the stages of seed development. There is evident a very close resemblance to the conditions found by the writer in *Alsine media* L.; nevertheless, a brief description of the developmental stages seen in *Cerastium vulgatum* L. may be of interest.

The ovules are somewhat compressed, and campylotropous. The mature megaspore enlarges and gradually dissolves the nucellar tissue, so that at the time of fertilization the embryo sac occupies a curved central position in the ovule, being separated from the integuments by a layer of nucellar tissue two or three cells in thickness. The structure of the integuments is as described for *Alsine media* L., the dome-shaped cells of the outer layer of the outer integument being evident even at the time of fertilization. A few compound starch grains are evident in the

cells of the nucellus adjacent to the embryo sac at the time of fertilization.

The early stages of embryo development agree with those of *Alsine media* L. The young embryo (Fig. 1) has a five-celled suspensor, the cell nearest the micropyle being broader and several times longer than each of the remaining cells. A large vacuole appears in the broadened portion of the large cell. Numerous endosperm nuclei are evident in the embryo sac by the time the seed development has reached the stage shown in Figure 2. The protoplasm of the endosperm is more abundant at the micropylar end of the embryo sac and also at the opposite end of the sac. The embryo at this stage is spherical with no indications of cotyledons. The smaller cells of the suspensor have elongated somewhat, so that their long axis is equal to their diameter. Numerous compound starch grains are now evident in the cells of that part of the nucellus (Fig. 3) which is encircled by the curved embryo sac and which lies between the embryo sac and the inner integuments. The chalazal region of the nucellus is practically free from starch, and remains so during the further development of the seed. The compound starch grains are made up of a smaller number and larger parts than those in *Alsine media* L.

As development proceeds the embryo sac becomes a little longer and broader. Cell wall formation appears in the micropylar portion of the endosperm. This cellular condition merges into the free nuclear condition of the rest of the endosperm, and appears at about the time that the cotyledons are beginning to be evident in the embryo. The suspensor becomes crushed by the enlarging embryo.

The mature seed shows a marked similarity to the condition found in *Alsine media* L. in many respects. The seed of *Cerastium vulgatum* L. is light brown and about six tenths of a millimeter in width, while the seed of *Alsine media* L. is dark brown and nine tenths of a millimeter in width. The seed in both species is flattened and shows surface elevations which are arranged in regular concentric rows following the general form of the seed. These elevations are the dome-shaped cells formed by the fusion of two or three integument cells.

The well-developed embryo is curved and extends almost the entire distance around the periphery of the seed (Fig. 5). The hypocotyl and radicle are circular in cross-section and equal in length to the cotyledons which are semicircular, their flat surfaces being in contact (Fig. 4). A cone-shaped plumule is evident at the base of the cotyledons. The nucellus between the embryo and seed coat is represented by one or two layers of cells filled with starch (Fig. 5). The remaining nucellar tissue, except that in the chalazal region, is also filled with starch. In *Alsine media* L. the cells in the region where the embryo comes nearest to the seed coat were crushed and no starch was present. The endosperm is represented by a cap of cells, as in *Alsine media* L., which fits over the tip of the radicle of the embryo.

SUMMARY AND CONCLUSIONS

The campylotropous ovule is very similar in its development and mature condition to that of *Alsine media* L. The curved centrally placed embryo sac is almost completely filled by the curved embryo; the only evidence of endosperm is a cap over the tip of the radicle, this cap of cells having dense cell contents. The starchy perisperm constitutes the major storage tissue of the mature seed.

The marked similarity seen in the seed development of *Alsine media* L. and *Cerastium vulgatum* L. is in accord with the similarity observed in their floral characters and method of growth.

Michigan State College
East Lansing, Michigan

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DESCRIPTION OF PLATE XVIII

All figures drawn with aid of camera lucida. Figures 2 and 5 from longitudinal section cut parallel to flat surface of ovule. Figure 4 from longitudinal section cut at right angles to flat surface. The following abbreviations are used: E, embryo; ES, embryo sac; S, suspensor; P, perisperm; SC, seed coat; M, micropyle; F, funiculus; NP, nucellus; EN, endosperm; OI, outer integument; INI, inner integument; PLU, plumule; C, cotyledons; R, radicle.

Fig. 1. Young embryo and five-celled suspensor. The micropylar cell of the suspensor is much larger than the other four (× 207)

Fig. 2. Young ovule, showing campylotropous form, embryo sac, young embryo in spherical condition, and endosperm in free nuclear condition (× 75)

Fig. 3. Cell from nucellus, in stage shown in Figure 2, showing small compound starch grains and large nucleus (× 430)

Fig. 4. Mature seed showing cross-section of radicle and cotyledons. Perisperm consists of cells which are closely packed with compound starch grains (× 40)

Fig. 5. Mature seed showing curved embryo about the centrally placed perisperm. The endosperm is evident as a cap over the end of the radicle (× 75)

PLATE XVIII

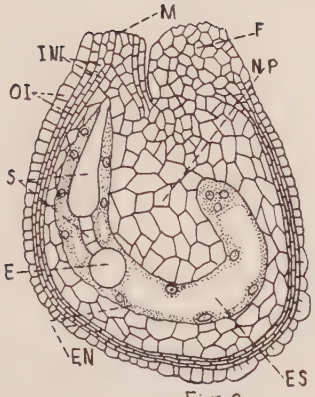

Fig 2

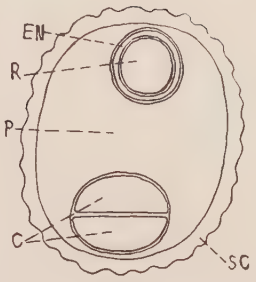

Fig. 4

Fig. 3

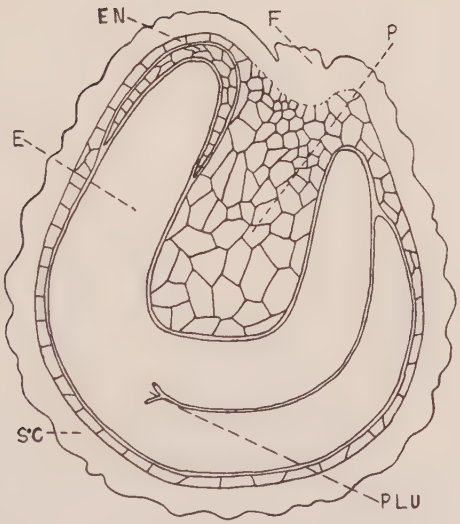

Fig. 5

Fig. 1

EXTRA-FLORAL NECTAR GLANDS OF *MALUS MALUS* AND *PYRUS COMMUNIS*

EDWARD F. WOODCOCK AND EDGAR C. TULLIS

ON THE extra-floral parts of plants there have been reported nectar glands for a large number of species. The distribution and structure of the glands vary to a very marked degree.

Wilson (3) reports nectaries on the petioles of *Acacia lophantha* Willd. (= *Albizzia lophantha* (Willd.) Benth.), the stipules of *Vicia faba* L., the blades and petioles of *Prunus laurocerasus* L., and the leaves of *Acer pseudoplatanus* L. Extra-floral nectaries have also been reported on the leaf of cotton, turban squash, poplar, passion flower, certain ferns, castor bean, and associated with cacti spines. Reinke (11), in 1876, published the results of a very exhaustive study of secretory organs of eighty-five different species, covering a wide range of genera.

Other investigators have made contributions to our knowledge of extra-floral glands, which have been found on practically all parts of the plant above the ground. Solereder (2), in his description of the conditions found in the family Rosaceae, states that ordinary external glands, with a uni- or bi-seriate stalk, and a more or less distinct head which is of variable size, multicellular or more rarely composed of one or two cells, have been observed by Kuster in Licarnia, by Fritsch in Rubus, and by Reinke in Alchemilla, Fragaria and Sanguisorba. He associates with the foregoing structures the following: (*a*) the glandular shaggy hairs provided with a stalk of varied length and a spherical or club-shaped head, found on the vegetative and reproductive organs of the genus Rosa and the genus Rubus, on the stipules of species of Prunus and Pyrus, and on the leaf-teeth of species of Prunus; (*b*) the analogous and almost sessile glandular structures (necta-

ries) on the petiole of species of Prunus; (*c*) the glandular leaf-teeth in species of Cydonia, Crataegus and Pyrus; (*d*) the glands on the leaf base of certain species of Parinarium; (*e*) the large leaf glands, described by Kuster as palisade-glands, which are visible even with the naked eye, and occur in Hirtella, Licania and Moquilea; and (*f*) the glandular spots on the lower side of the leaf of *Prunus caroliniana*.

Solereder further states that the petiolar glands of Prunus are merely glandular shaggy hairs with a short stalk and large spherical head, which is somewhat depressed on the upper side. The secretory leaf-teeth of the species of Crataegus, Cydonia and Pyrus have somewhat diverse structure, but agree in their epidermis being made up, in part at least, of palisade-like tissue and in enclosing terminations of veins. According to Reinke (1), secretory leaf-teeth, with no palisade-like epidermis, also occur in other members of this order (Alchemilla, Fragaria, Kerria, Rubus, Sanguisorba and Spiraea). Terminations of veins, however, enter the leaf-teeth; and the epidermis in all the foregoing genera, except Kerria and Rubus, contains a group of water pores.

This paper represents the results of an investigation of the structure and location of the extra-floral nectar glands in *Malus malus* (L.) Britton and *Pyrus communis* L. The general distribution of the glands was studied by means of a hand lens and the detailed structure was gained by a study of microtome sections stained in Delafield's haematoxylon. The general structure of the glands found agrees quite closely with extra-floral nectar glands described by other investigators. The writers have made no detailed study of the chemical nature of the secretion and they are justified in calling them nectar glands only because of their anatomical features and the sticky nature of the secretion.

The location and general structure of the extra-floral nectar glands of *Malus malus* (L.) Britton and *Pyrus communis* L. are so near alike that the following description will apply to both with a few exceptions which are noted in the discussion.

The glands are evident on the leaf blade, petiole and stipules, at the time the leaf unfolds from the bud.

On the leaf blade the glands are located on the upper surface

at intervals along the midrib. In the apple they are also present along the main lateral veins, the number of glands decreasing toward the leaf margin.

The rather blunt leaf-teeth also possess glands. Small glands are also evident in the axil of many of the teeth (Fig. 3). There are no glands on the petiole except in the axil of the stipule and in the axil of the petiole (Figs. 4–5). In the former location two or three glands appear on the upper surface of the petiole in the axil of each stipule. In the axillary region of the apple petiole only, there are present, on the petiolar surface, numerous glands, closely placed and sometimes appearing one above the other (Figs. 2, 5). The glands are usually most abundant at the ends of the axillary region. The terminal portion of the few teeth present on the stipules of the apple is modified to form a gland (Fig. 6). No other glands appear on the stipular surface. The margin of the stipule in the pear is smooth and the gland arises at any point along the margin.

As Reinke only briefly describes the structure of the glands, the writers feel that a complete description will be of scientific interest. The commonest type of gland is club-shaped, being about two tenths of a millimeter long and one tenth of a millimeter wide. The end of the gland is pointed or flattened and the supporting stalk is very short (Figs. 1–2). Associated with the type of gland in the leaf axil there is often a smaller somewhat spherical, sessile gland, occupying a position just below the club-shaped gland (Fig. 2). These glands have an axial region of cells and an epidermal layer, the latter consisting of palisade-like cells whose long axes are at right angles to the surface of the gland. The axial region in the club-shaped glands is made up of long parenchyma cells, while in the spherical type nearly isodiametric cells are present. The epidermis of all the glands is furnished with a well-developed cuticle. No observations were made on the fate of the cuticle in the secretion process. There is no evidence of a vascular strand ending just below the base of the glands of the leaf axil or of the pear stipule margin.

The glands on the leaf margin are located at the end of the teeth and also sometimes in the axil of the leaf-tooth. The

glands on some of the leaf-teeth are club-shaped, similar to those described above, while others have a short conical gland. The gland in the tooth axil is smaller and also conical (Fig. 3). A vascular strand ends just below the base of these marginal glands. The shape and structure of the glands on the smooth margin of the pear stipule are quite similar to the club-shaped glands in the leaf axil (Fig. 3). The conical stipular glands of the apple occur at the end of the blunt teeth and the palisade-like secretory epidermal cells surround an axial region which is separated by only a few cells from the end of a broad vascular strand.

The young glands on the various parts of the actively growing leaf are light green and their secretory epidermal cells show dense protoplasmic contents. As the leaf becomes mature the glands become yellowish-brown and the secretory cells very much vacuolated. Finally the glands become shrivelled and are easily dislodged.

SUMMARY AND CONCLUSION

The glands found on *Malus malus* (L.) Britton and *Pyrus communis* L. show a structure which leads the writers to use the term "nectar gland" in describing them. In the apple they are located on the upper surface of the leaf blade, along the margin of the leaf blade and stipule, in the axil of the leaf petiole, and also in the axil of the stipule. In the pear a similar condition exists except for the petiole axil, where no glands are present. The glands show an epidermal secretory layer of palisade-like cells, and usually an axial region of elongated cells. In no specimen was a vascular strand observed entering the glands.

The writers have not carried the investigation far enough to come to any conclusion as to the function of the glands. Reinke, in discussing the glands of *Prunus avium* L., states that bees do not seek the honey given off, but ants greedily devour the secretion. Perhaps such may be the function of the glands discussed in this paper.

Michigan State College
East Lansing, Michigan

PLATE XIX

PLATE XIX

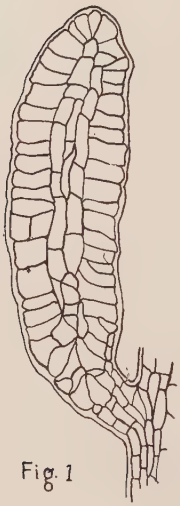

Fig. 1

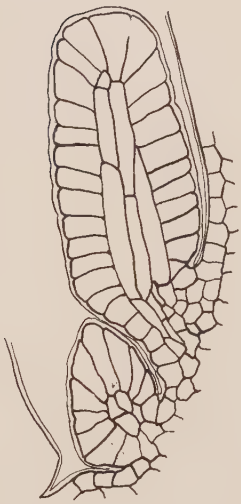

Fig. 2

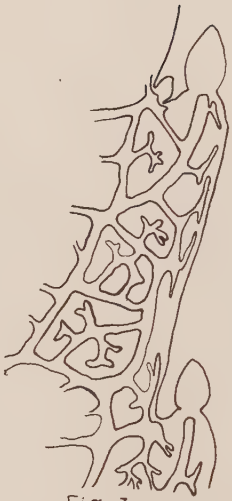

Fig. 3

Fig. 4

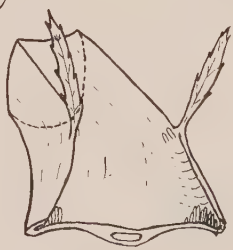

Fig. 5

Fig. 6

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DESCRIPTION OF PLATE XIX

All drawings from microtome sections except Figure 5, which is a diagram.

Fig. 1. Gland from margin of pear stipule (× 207)

Fig. 2. Glands in axil of apple petiole (× 207)

Fig. 3. Margin of pear leaf showing gland at end of tooth and in axil of tooth (× 40)

Fig. 4. Longitudinal section of node showing gland in leaf axil of apple (× 13)

Fig 5. Diagram of base of petiole showing stipules and glands of apple (× 13)

Fig. 6. Marginal tooth and gland of apple stipule (× 430)

SOME SOCIAL TRENDS IN AGRICULTURE

KENYON L. BUTTERFIELD

AMERICAN agriculture during the past five years has been undergoing an economic depression that relatively is the most serious in American agricultural history. The depressions of the 'seventies and of the 'nineties were serious enough in their way, but in neither of these decades had agriculture yet come to its full maturity as a commercial enterprise nor had the new land been entirely absorbed. Now, however, the new land is practically gone and there is ample proof that much of the land that has been farmed during the past half century, by reason of lack of natural fertility or by reason of poor treatment, is not farmed profitably. Meantime industry has had perfectly enormous development economically and is in the saddle politically. The fact of this depression is mentioned because it has much to do with the social trends that are now observable; indeed, although it is not the only factor, it is possibly the decisive factor in the stream of tendencies.

With these remarks as a background we may say that the outstanding fact in our American agriculture from the social point of view is the apparently unabated shift of population, more particularly the migration from the farm. Since the war this migration has assumed larger proportions than ever before, both numerically and relatively. Prosperous industry at high wages during a period of low prices for farm products has called literally millions of young men from the farm to industrial centers. From the standpoint of causes, one might refer to an address in which Dr. T. N. Carver has recently called attention to some of the factors in rural depopulation — to the fact, first of all, that rural migration is one of the oldest of our social phe-

nomena and is still going on. Here in the United States, the inability to expand the demand for any of the great staple crops, he feels, is a large factor because it commits our prosperous people to consume staples at about their per capita capacity, and to buy luxuries both in food and in other things, particularly other things. Along with this has gone an enormous increase in the capacity of the farmer to produce units per capita of farm workers. Farm machinery has been a major factor in this increase and now there comes the additional asset of new sources of power to run machinery.

A counter movement away from the city has also attained considerable proportions and is probably in its infancy. It is not, however, a return to the farm. It is the building up of the suburban population. Dr. H. P. Douglas states that in 1920 in sixty-eight cities having twenty-seven million population, there were in adjacent suburban territory nine million people, about a third as many as inhabited the cities themselves. This suburban development takes many forms: that of mere residence and commutation; that of residence in satellite communities dependent upon the great city and having a certain social self-sufficiency; that of residence on the fringes of the city which includes a parcel of land for the purpose of either aesthetic or economic advantage to the new owner, a form used largely by wage workers, whereas the first type is made up largely of professional and business people. And then there is still a residuum of intensive farming within the metropolis areas. Douglas says that there is a total farm population of over fifty thousand people within the limits of incorporated cities of over twenty-five thousand.

Another aspect of the population shift as it affects rural affairs is one that is probably of less moment for the present than either of the others, but one that may be of considerable significance for the future, namely, the steady seepage of foreign born or of children of the foreign born onto the farms made vacant by owners who were in most cases either Americans or whose ancestors were from English-speaking areas. There does not seem to be much recent colonization by the foreign groups. Some of the newcomers enter into the foreign communities, but most of them

filter into the old English-speaking groups as the farm owners give up their desire to retain farm connections.

Another trend in farm life is toward substantially higher standards of living. This fact is probably due more largely to the influence of urban and town standards than it is to sheer ambition or to particular prosperity on the part of the farmer. Indeed, it is probably true that one of the elements in the present agricultural depression is the fact that higher standards have come more rapidly than the means of supplying them. Some recent studies seem to indicate that the standards of living of our farmers are almost identical with the standards of living of wage earners, not only for total amounts spent, but for percentages of expenditure for particular purposes, like education, etc.

The underlying phenomena in our present agriculture seem to be, therefore, a serious economic depression, a continuing and increased shift in population, and a sharp rise in economic standards of living.

It is a little difficult to separate conditions and causes and consequences in a discussion of this sort, but we may now mention with as much concreteness as possible some of the consequences of the conditions described. The consequences themselves, however, constitute very decidedly a part of the social trends in agriculture.

First of all, we have the fact of the serious lack of farm labor. This is a bit of a paradox. There are too many farmers, yet there are thousands of farmers in every state who find it increasingly difficult to carry on their normal operations because of the lack of labor. This situation is probably due to the fact that while farm machinery has vastly increased the productive capacity of the farmers as a whole, there has been an exceedingly uneven depletion of a labor supply sufficient to utilize that machinery to the full capacity of the farm acreages that have been established. The cutting down of acreage, even the abandoning of farms, is a frequent result. Of course, from the economic point of view, we do not want an excess of farmers. From the social point of view, however, we would like to be sure that those who remain are of the requisite quality, and the query

arises whether in a country which has always had a relatively small proportion of laborers to its working farmers, the depletion of the labor supply may not crowd the working farmer himself into lower levels of social life.

Standards of life as well as standards of living have changed the old physical isolation of the farmer and have been almost completely transformed by the advent of the automobile and better roads, although it should be said in passing that, psychologically, the farmer still exhibits and will for a long time exhibit many of the results of physical isolation. He still works much by himself and he has time to think or brood as the case may be. His family is an isolated family. Nevertheless, the chances for getting about and for relief from the grind and monotony are having a profound effect upon the farmer's attitude toward life.

The American farmer has learned at least to respect education in the sense that he now sees that the application of science to his task is normal and inevitable and is the price he must pay for success. There is still prejudice and there is ignorance with regard to even well-established processes of good farming, but I think that most of this lack comes from just the normal human lack of energy and enterprise. The enormous and effective system of coöperative extension work, as carried on for the last fifteen years, is probably largely responsible for this changed attitude toward education.

Probably the most significant consequence of what has been happening in rural affairs is the breaking up of the old groupings and a consequent breaking down, and a resulting chaos, in rural social institutions. With the exception of the town in the earlier days of New England, and certain communities which have established themselves in spots all over our country, we have never had true rural communities. The individual farm and farm family have been the unit. The political subdivisions of town and county have meant very little from the social point of view. Few farmers have lived in villages and there has not only been no attachment to the neighboring villages on the part of the farmers but often sharp separation

and even antagonism. There have been farm neighborhoods by the multitude grouping about families, district schools, country churches, granges, etc. But these old groupings have now been very largely broken to pieces by reason of the fact that contacts both economic and social can be made so quickly and so easily with centers of population.

The small district school began to suffer nearly a generation ago. The development of consolidated schools has gone on apace during that period but has been very irregular, both nationally and within the states themselves.

The breakdown of the church has been slower, partly because the remedies for existing difficulties were not so easily applied. Overchurching in some areas and underchurching in others are not easily eradicated. There are many prejudices and traditions; there are sharp denominational rivalries and competition, and the whole burden of institutionalism rests upon the country church. It is not easy to make changes. All sorts of difficulties arise. But there can be no doubt about the general fact that the country church has been seriously weakened.

It is impossible to trace changes in the work of the so-called farmers' organizations due to changes in population. The grange has undoubtedly been weakened somewhat by new organizations although it still holds on in many ways and in many parts of the country. The character of the grange work has probably been considerably changed by the ease of getting about and finding entertainment elsewhere. It has even been suggested that the area of operations of a local grange should be widely extended. The new coöperative organizations have followed market currents and have had no relationship whatever to the history of either church or school.

And then finally, all these trends are resulting in new occupational attitudes; attitudes, however, not easy to analyze in satisfactory fashion. There is certainly a new attitude on the part of country men. Many farmers who have left the farm have gone in disgust, glad to get away. Many of those who stay are resentful. The tendency to adopt urban standards of living has, however, eliminated many of the old prejudices that existed toward

city people. It is difficult today to distinguish city people from farmers in any gathering where both groups are present, at least as far as dress is concerned, although it is probably still true that the hands of the golfer are not yet quite the hands of the plowman. In the large, however, there is going on the most significant agrarian movement that America has ever seen, and it promises to have a profound bearing upon our American life economically, socially, politically. The farm bloc is a political expression of this new occupational attitude.

In discussing reorganization, one has to refer frequently both to conditions and causes as well as to their consequences. Let us consider some of the general problems very briefly in the light of what seems to be happening or likely to happen.

First of all, the suburban development apparently does not have much effect upon farming or farm life as such. It is a trend of great significance to the city from every angle and has much to do with the future of our civilization, but it has, so far as I can make out, very little to do with rural development itself.

Of the utmost consequence, however, is the striving after new groupings. These are of all sorts. First of all in social importance, although not yet well developed, is a tendency toward the formation of a town and country community by which the village or small city which is not industrialized to any extent and is therefore almost completely dependent upon the farms around about it, is tied up with the farmers within a radius of six or eight miles. Not much has been accomplished thus far except to break down the old antagonisms and the old walls of separation, but there are signs indicating that efforts will be made to establish programs of coöperation and development involving the new type of community.

What is happening, however, is the attempt to make new arrangements for administration for special purposes. These usually center around some new type of institution. One may mention such things as county administration of roads and road-building, the tendency to establish the county unit for school administration, the county unit for administration of welfare work, the work of county hospitals and of county libraries,

and the county agricultural agent and home demonstration agent. There are frequently county federations of various organizations. The American county, therefore, which outside New England, has always been a fairly active political unit, is now becoming a fairly active social unit. For example, in all the more populous agricultural counties, automobiles and roads make it possible for the large majority of the farm people to reach the county seat from their homes in an hour or less, — in other words, in an average time less than that of the average commuter in the great city. A modification of this county organization is the development of some sort of district for coöperative work which may comprise parts of several counties or of townships within a county.

This tendency to make new social groupings around social institutions, while it has been brought about very largely by the fact of new types of institutions and newly recognized needs, is, of course, having a profound effect upon the old institutions, particularly upon the school and church and in the grange as well. It is largely responsible, although not wholly, for the consolidated rural school. It has played havoc with the country church. In Michigan the tendency toward consolidated schools is a very slow one. Yet consolidation seems to be the only way to an adequate rural school. What has happened in our state, however, is that a very large proportion and, in some places, a majority of the pupils in the smaller high schools of the state are farm boys and girls. This fact in itself has probably retarded development of the consolidated school as these youngsters during their early schooling are taken care of reasonably well in the one-room schoolhouse.

The grange with its local unit organized on the basis of an area practically that of the typical western township, is suffering in the same fashion. Whether it will organize into larger effective units is still a question.

The case of the church should give us the greatest concern. We have not only the old sectarian divisions that resulted in overchurching, but we have also the fact that there is no need any longer for such a multiplicity of churches, and the further

fact that in comparison with the village or town church the open country church will be at a distinct disadvantage. Personally, I think the way out lies in the development of a larger parish, interdenominational if possible, denominational if it must be, which will have its center in the town that forms the nucleus of the future town and country community, with such out-stations as may be necessary to make its work completely effective among the farm people, and with a staff of two to half a dozen workers, one or more of whom will actually live in the country and every one of whom will have a special field of service and be specifically trained for it. Perhaps it is too much to say that this type of organization is a trend, but I think it is. At any rate, it is a prophecy.

When we come to recreation, health, care of the defectives, etc., I am inclined to think that we are going more and more to the county basis of organization and administration and interest.

With respect to the general question of attitudes, we are apparently entering a fairly long period of agrarian aggressiveness. Under the present method of political subdivisions into representative districts, the farmers of the country, if they so choose, can dominate legislation for years to come. There are several reasons why they don't dominate at present. One is because they are not organized; another is because they have had tremendous political prejudice and have followed the traditional party loyalties; another is that they have sectional and regional diversities of interest that at present keep them apart and that may always keep them apart. Industry is so powerful, so committed to expansion, so fully tied up with urban or at least suburban interests that the farmer is very likely to be left in the lurch. Questions like the tariff, taxation, credit, the spread between farm prices and consumer's prices, the place of agriculture in world commerce, all these economic problems have come to the acute stage as they affect the relationships of American agriculture and the other economic interests of the nation. The solution of these problems is interesting and significant enough, but their relationship to a much more fundamental consideration, namely, the quality of the population that will be left on the

land a generation from now and two generations from now is, after all, the abiding issue. Here again, a bit of prophecy is ventured to the effect that a proportion, perhaps 10 per cent of the American farmers of the future, will be technically the best farmers and the most prosperous farmers in the world. Their standards of living and standards of life, their community influence, their social institutions will be fairly comparable with those of any other part of civilization. But I fear that the tendency at least of the stream of human events is toward a gradual slipping of our farm population in comparison with city populations, and particularly in comparison with the characteristics and qualities of the American farmers of the past, who occupied a position of great capacity and influence. If we are to avoid this trend toward diminution of quality, I think we must have an American statesmanship that recognizes that economically the farmers must be given a favored position. We must have the development of real town and country communities with adequate programs of social development. We must have such a reorganization of our social institutions, particularly of the church, as will raise the standards of American rural life.

Michigan State College
East Lansing, Michigan

AN ECONOMIC SURVEY OF CHIPPEWA COUNTY, MICHIGAN

WADE E. DeVRIES

IN A geographic study the first item to be considered is the natural environment. In studying the natural environment of Chippewa County, Michigan, the various natural features such as soil, drainage, topography, location and forest growth are considered in relation to one another as forming natural districts. Because of the interrelationship of these features, it follows that a certain soil is associated with a certain class of topography and a certain type of forest cover. Likewise, a certain forest type naturally associates itself with a certain soil type and a certain degree of drainage. In Chippewa County, the natural districts as defined on this basis are very definite and distinct units with easily apparent boundaries. Each district possesses a unity of character and contrasts strongly with every other district. There are no commonly accepted local names for any of the natural districts in this county, except perhaps the "plains" or "pine plains." In the absence of such names, these districts have been named, for the purpose of this article, from their most significant natural features. The map (Fig. 16) shows the location, extent and names of the natural districts of Chippewa County. Natural conditions are not absolutely uniform throughout each district. Small areas here and there offer contrasts. Nevertheless, each district is sufficiently uniform in natural features to be easily recognized as a unity.

The Clay District is an area of prevailingly heavy clay loam soils, locally known as "red clay," which are its most distinguishing natural feature. The surface soil is acid but the subsoil is alkaline. There are some areas of swamp over clay, the largest

being in southern Bruce Township and northeastern Pickford Township. Any other swamps are of small extent and unimportant. This district is high in natural fertility. The topography is nearly level, the elevation varying from 650 to 700 feet over a wide area. The drainage is fair to slow. The forest growth is made up of hardwoods principally with softwoods such as poplar on the burned over areas. Swamp conifers are found on the more poorly drained parts. This district corresponds very closely geologically to the clay deposit in Lake Algonquin.

The Shore Border District consists of a strip of land extending along the shore of St. Mary's River, Whitefish Bay and Lake Superior. This land all lies on the first low bench above the present lake level. In most places, there is a very prominent old lake bluff that marks the boundary between this district and those adjacent. The soil consists of sands and sandy loams underlain by heavy clay. Areas of clay soil occasionally occur. The clay is often at a depth sufficiently shallow to hold the moisture up in the sandy loam of the surface. This surface has an acid reaction but the subsoil is alkaline. The natural fertility ranges from high to low. The small patches of alluvial soils are exceedingly fertile, but in localities where the clay is deeply buried by sand, the fertility is very low. The soil in general lacks the uniformity that is found over large areas in the Clay District. The topography is level to undulating. The natural drainage is adequate to poor. The forest growth consists of poplar, white birch and other softwoods on the cut over and burned areas, and conifers in the swampy parts. Hardwoods are found on the better drained parts. This district corresponds geologically to the Post-Nipissing sand and clay. Its location on the shore border is its most important and most significant natural feature.

The Sandy Hardwood Upland District is made up of all the areas of sandy hardwood soils. The largest block of this type of country is in the western and more unsettled part of the county, although there are several patches of this type in the eastern part. The soil is a light sandy loam and prevailingly acid in reaction. In the southeastern part of the county where the Hardwood District extends into the Stony District, as shown on

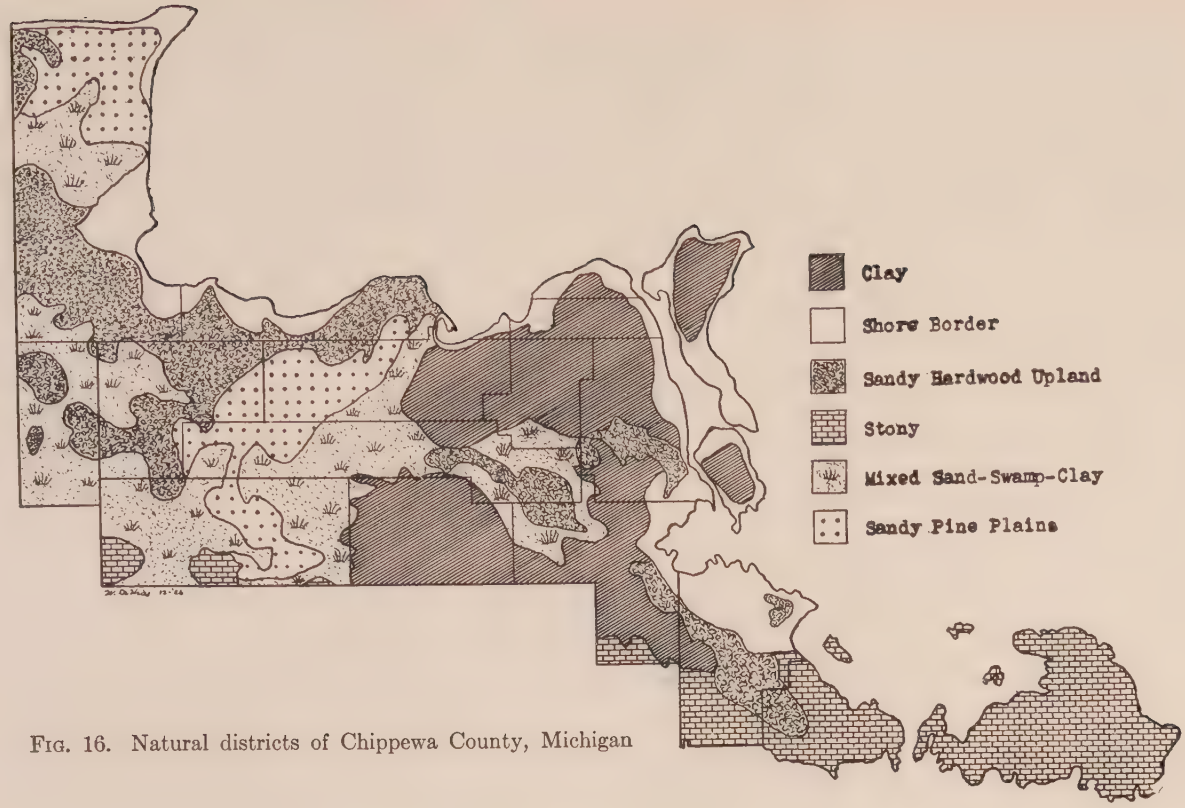


FIG. 16. Natural districts of Chippewa County, Michigan

the map (Fig. 16), the soil is somewhat alkaline. The natural fertility of this district is moderate to low. The topography is undulating to rolling. The natural drainage may be described as free. The forest growth consists principally of hardwood, maple and beech. Softwoods such as poplar make up a large part of the stand on the cut over and burned over areas. Most of this district corresponds geologically to marginal moraines.

The Stony District consists of the areas of shallow limestone soils in the southern and southeastern part of the county. The soil is prevailingly a very stony loam. The entire district is underlain at shallow depth by limestone bed rock which frequently outcrops over areas as large as forty acres. The soils are prevailingly high in lime and not acid. They are very fertile, but so exceedingly stony that their agricultural use is very limited. The topography is as a rule gently rolling to level, but with a few outstanding rocky hills, which are the most outstanding relief feature in the county. In the southwestern part of the county, they reach an elevation of 1,000 feet above sea-level, or from 250 to 300 feet above the surrounding country. The subsurface drainage in the Stony District is imperfect, being interrupted by bed rock at or near the surface. There are many small lakes, and swamps are common. Softwoods, swamp conifers and hardwoods constitute the forest cover. The outstanding natural feature which accounts for the soil, topography, drainage and timber is the limestone rock at or near the surface. Geologically, this district is partly till plain and partly sand deposit in Lake Algonquin.

The Mixed Sand-Swamp-Clay District occupies that transition zone between the Clay District and the Sandy Pine Plains, and between the Clay District and the Sandy Hardwood Upland District. It also includes that area in the southwestern part of the county between the Stony and the Hardwood Upland Districts and also most of the large swamp areas of the county. Most of the swamp and wet sandy lands outside the Shore Border District are included in the Mixed Sand-Swamp-Clay or Transitional District. Near the border of the Clay District, the sand is underlain at a shallow depth by clay, the clay holding up

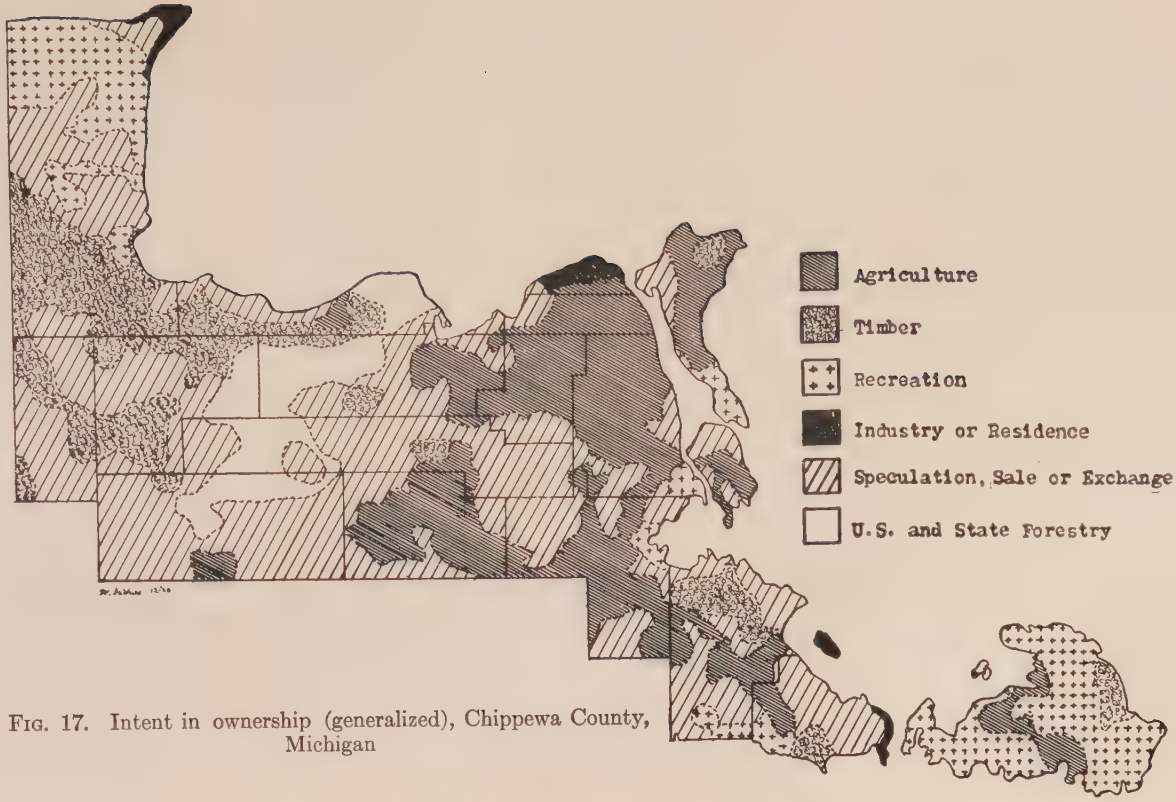


FIG. 17. Intent in ownership (generalized), Chippewa County, Michigan

the moisture and keeping the sand wet, while near the border of the Plains or Hardwood the sand becomes nearly dry. The distinguishing characteristic of this district is the lack of uniformity in soil over any considerable area. This characteristic is expressed in the name. The soil is prevailingly acid with the exception of that part bordering the Stony District, where it is somewhat alkaline. The natural fertility is moderate to low. The topography is level to undulating. The drainage is as a rule poor. The forest cover consists principally of swamp conifers with softwoods and hardwoods on the sand ridges. The surface geology is described as sand deposit in Lake Algonquin.

The Sandy Pine Plains District extends in a belt from northeast to southwest across the west central part of the county. It also occupies an area near Whitefish Point. The soil is prevailingly a coarse sand which is very acid and low in fertility. The topography is nearly level. The drainage is excessive, making the soil very droughty. There are practically no streams and no run-off, rainfall draining downward through the sand. The forest cover consists principally of jack pine with scattering areas of Norway pine. Large areas were originally devoid of merchantable timber. The district is now locally known as "jack pine plains" or "the plains." Geologically, it consists of outwash plain and sand deposit in Lake Algonquin.

All the facts presented thus far are true for all time, regardless of the stage of development. It will be noticed that no one feature, such as soil or topography, is sufficient in itself to form the basis of this classification, but each district has a distinctive combination of natural features. (See plates at end of text.)

LAND OWNERSHIP

Inquiry was made regarding the intention of the owner of each parcel of land in the county by the following method. Township plats showing the name of each owner of acreage property were placed before the local assessing officer, as he is the officer most familiar with the plans and policies of the landowners in his district. The local assessor was asked to give his opinion regarding the intent in ownership of each parcel of land

in his district. By his answers it was found to be possible to group the intent in ownership into several classes.

The distribution of six principal classes of intent in ownership is shown in Figure 17.

This map is generalized in that the greater part of the area indicated as "agriculture" has by far the greater part of its area in this type of ownership, although there are forty or eighty acres here and there that are in other classes of ownership. The area shown as "timber" has the greater bulk of its area in this type of ownership, although other classes of ownership are scattered here and there in the area. The same is true for the other areas shown on the map.

A comparison of Figures 16 and 17 indicates the close relationship between the Clay District and the Agricultural District. In those sections where the boundaries of the Clay District (Fig. 16) extend out beyond the Agricultural District (Fig. 17), the earliest expansion of agriculture may be expected. A close relationship is seen to exist between the Sandy Hardwood Upland (Fig. 16) and the Timber District (Fig. 17), also between the Mixed Sand-Swamp-Clay (Fig. 16) and the land held for speculation, sale or exchange (Fig. 17) and between Sandy Pine Plains (Fig. 16) and U. S. and State Forestry (Fig. 17).

Figure 18 shows the exact correlation between the natural districts and intent in land ownership in Chippewa County.

Intensive recreational land, such as lake shore cottage sites, is of importance in the Shore Border District. Extensive recreational development in the nature of private hunting lands is of importance in the Stony and in the Pine Plains Districts.

ECONOMIC CORRELATION

The following table of selected data of an economic nature will indicate the correlation between economic and natural features:

CORRELATION BETWEEN ECONOMIC AND NATURAL FEATURES

	Clay	Shore Border	Sandy Hardwood Upland	Stony	Mixed Sand-Swamp-Clay Transitional	Sandy Pine Plains
Valuation, per acre, of undeveloped land (not timbered)	$10.50	$ 8.60	$ 6.70	$ 3.20	$ 5.50	$ 3.30
Valuation, per acre, of owner-operated farms	26.50	14.50	8.50	3.40	10.10	—
Valuation, per acre, of rented farms	29.10	29.10	11.50	8.40	10.30	7.50*
Valuation, per acre, of abandoned farms	11.40	3.60	4.30	2.40	8.50	3.80
Percentage of all farms owner-operated	80½	87	79	75	79	—
Rented	17½	7	7½	2	10	22*
Abandoned	2	6	13½	23	11	88
Population, per square mile	20½	8½	6	3½	2	1

* Only 1 farm (80 acres)

The valuation indicated above is the equalized valuation put upon land and buildings for the purpose of taxation. The valuation of one parcel of land is to the valuation of another parcel of land as the local appreciation of the qualities of parcels of land are to one another. This valuation is not productive value or

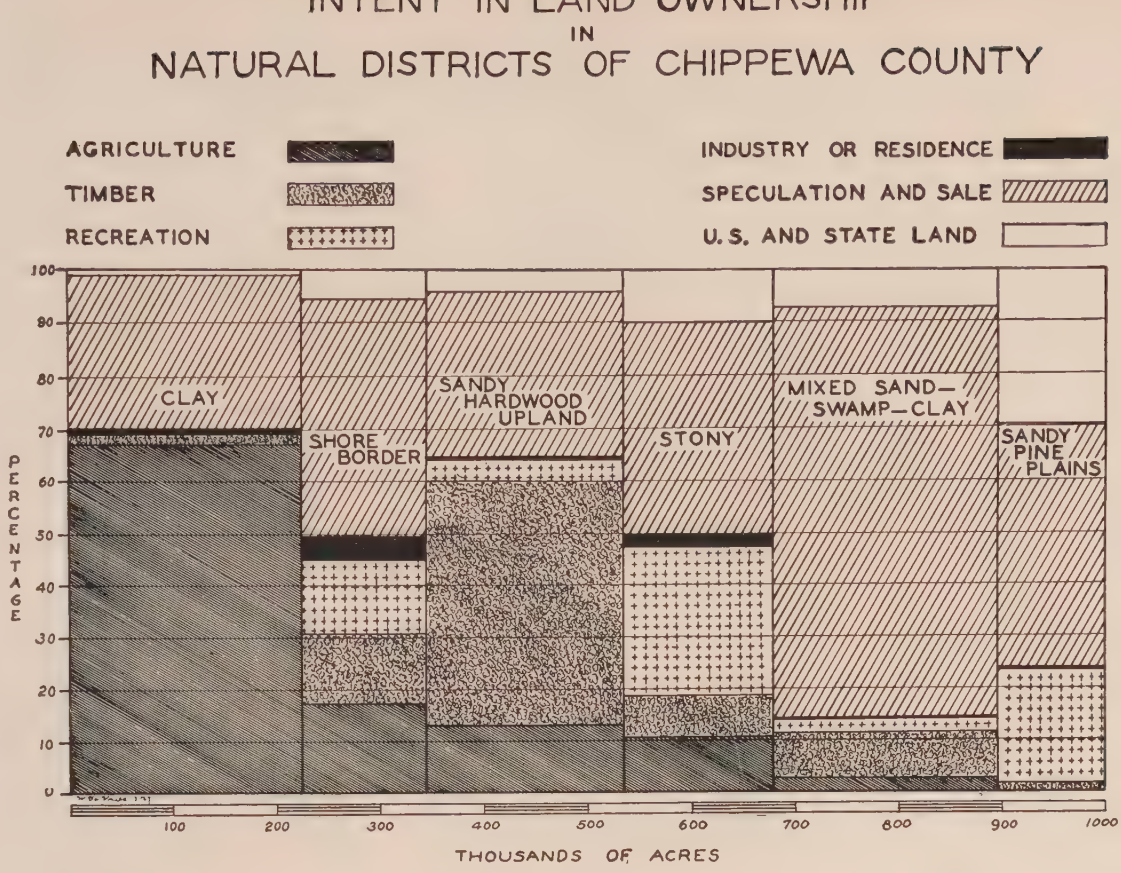

INTENT IN LAND OWNERSHIP
IN
NATURAL DISTRICTS OF CHIPPEWA COUNTY
AGRICULTURE
TIMBER
RECREATION
INDUSTRY OR RESIDENCE
SPECULATION AND SALE
U. S. AND STATE LAND
CLAY
SHORE BORDER
SANDY HARDWOOD UPLAND
STONY
MIXED SAND—SWAMP—CLAY
SANDY PINE PLAINS
PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
700
800
900
1000
THOUSANDS OF ACRES

FIGURE 18

selling value, but it is recognized as representing true proportional valuation.

The relative valuation of land held for speculation, sale, or exchange (undeveloped land) in each natural district shows the relative soil values, eliminating from consideration timber cover and improvement due to land clearing.

According to the valuation, the owner-operated farms on the Clay District are worth nearly twice as much as those in any of the other districts. The rented farms in both the Clay and the Shore Border Districts are worth over twice as much per acre as those in any of the other districts. The value of the average farm is lowest per acre in the Stony District This is as true of the rented farms as of the owner-operated farms. From these figures, it would seem that the Clay District is best suited for farming development and the Stony District and the Sandy Pine Plains least suited to farm development. These three districts have all been opened to farm development for about forty years. In all the natural districts of the county, the rented farms have a higher valuation, per acre, than the owner-operated farms. It is profitable to rent only the best farms. A farm on poor soil or a farm that is only partially developed will not support a tenant and pay rent.

In every district the abandoned farms have a much lower valuation than the occupied farms. They have the highest valuation in the Clay District, where abandonment does not occur on the clay lands proper, but on the patches of poorly drained or high but stony land. Such soil does not lack in fertility but the physical difficulties in cultivation are too great to be overcome, hence, the abandonment. The abandonment in the Mixed Sand-Swamp-Clay District has taken place on the margin of the clay lands where the land was too wet for cultivation without drainage. The valuation of the abandoned land here is nearly as high as such land in the Clay District. In the Shore Border, Sandy Hardwood Upland and Sandy Pine Plains Districts, the abandonment is the result of isolation or lack of fertility in the soil on which farming was attempted. In these districts the valuation is extremely low. The valuation of abandoned farm land in

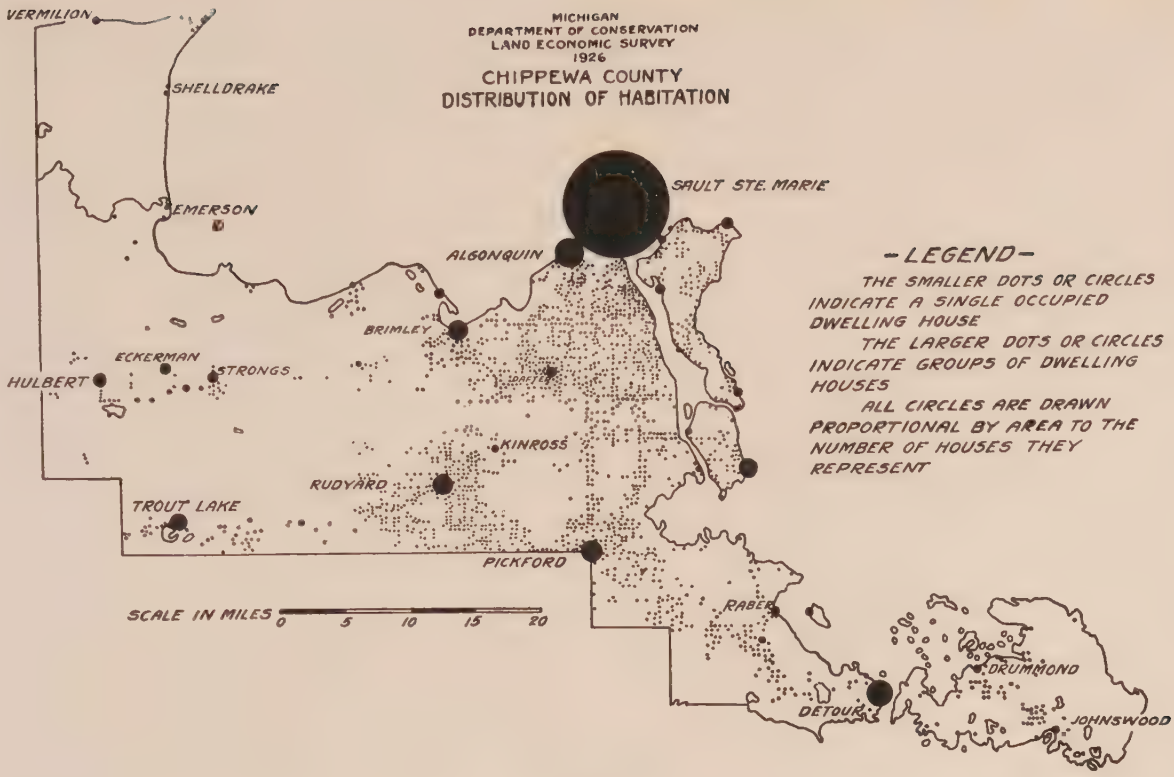

MICHIGAN
DEPARTMENT OF CONSERVATION
LAND ECONOMIC SURVEY
1926
CHIPPEWA COUNTY
DISTRIBUTION OF HABITATION
VERMILION
SHELLDRAKE
EMERSON
SAULT STE. MARIE
ALGONQUIN
BRIMLEY
ECKERMAN
HULBERT
STRONGS
KINROSS
RUDYARD
TROUT LAKE
PICKFORD
RABER
DRUMMOND
DETOUR
JOHNSWOOD
SCALE IN MILES 0 5 10 15 20
-LEGEND-
THE SMALLER DOTS OR CIRCLES INDICATE A SINGLE OCCUPIED DWELLING HOUSE
THE LARGER DOTS OR CIRCLES INDICATE GROUPS OF DWELLING HOUSES
ALL CIRCLES ARE DRAWN PROPORTIONAL BY AREA TO THE NUMBER OF HOUSES THEY REPRESENT

FIGURE 19

the Stony District is as low as for any class of land in the county and the farms that are occupied have a valuation that is not much higher. There are two reasons for this: first, the labor cost of preparing this stony land for cultivation and second, the difficulty of marketing produce in this district, most of which is over fifty miles from a railroad station.

Figures showing the percentage of all farm land owner-operated, rented and abandoned establish the fact that rented farms are associated mainly with the Clay District and are of relatively less importance in the Stony District and in the sandy districts. Farm abandonment is distinctly not associated with the districts where rented land is common.

DISTRIBUTION OF POPULATION

A summation of the productivity of land resources, as at present developed, is indicated by the density of permanent population supported in each district (see table). Figure 19 shows where the population of the county is located. An occupied house generally indicates the location of a natural resource that gives employment to people. The greater the concentration of habitations, the greater the concentration of developed natural resources. A comparison of the number of occupied dwelling houses in any area with the population as reported by the last U. S. census shows a population of between four and five persons per dwelling house. Most of the dwellings shown in the west-central part of the county, with the exception of those at Hulbert, are temporary tar paper structures built to serve during the period of the lumbering operation. Since they are not intended for permanent homes, no pride is taken in the matter of their appearance. The farm dwellings in the eastern part of the county offer a sharp contrast to this condition.

CONCLUSION

The work of the Michigan Land Economic Survey is concerned with an inventory of the resources of northern Michigan. The principal natural resources are soil, forest growth or cover

and water. The economic inventory considers the present status of utilization of these resources. The data which have been presented in this paper show that there is a decided relationship between natural and economic conditions.

In Chippewa County there is room for farm, forest and recreational expansion, but this expansion should recognize and be guided by this relationship between natural and economic conditions. An over-expansion of farming upon soils which are unsuited to it has resulted and will result in abandonment and consequent loss of wealth. An over-expansion of forest development to the detriment of the farming interests is unnecessary and undesirable. It is hardly possible for forest expansion to be anything but advantageous to recreational expansion. Farm, forest and recreational expansion is necessary to the complete utilization of this county's resources.

Department of Conservation
Lansing, Michigan

EXPLANATION OF PLATES

PLATE XX

Fig. 1. Typical forest cover in the Clay District. This is the type of land which is most promising for future agricultural expansion.

Fig. 2. The greater part of the Clay land is now in farms. Note the good road, large barns and prosperous appearance typical of the Clay District.

PLATE XXI

Fig. 1. Hay fields and large barns. No woods or woodlot is visible on the horizon. Woods are much less frequent than in southern Michigan.

Fig. 2. Hay and dairy products, the principal sources of income in the Clay District.

PLATE XXII

Fig. 1. Virgin hardwood forest on the Sandy Hardwood Uplands. Logs and chemical wood are the principal products of this District.

Fig. 2. After the lumberman and fire have gone over the land.

PLATE XXIII

FIG. 1. A farm failure on the Sandy Hardwood Uplands resulting in a loss of wealth. Hardwood reproduction in the background.

FIG. 2. The Upper Falls of the Taquamenon, site of a proposed state park; scenic beauty in the virgin hardwoods.

PLATE XXIV

FIG. 1. Another scenic spot in the Sandy Hardwood Uplands. View from Mission Hill, Spectacle Lake, in foreground. Head of St. Mary's River in background.

FIG. 2. A view in the Stony District. Note the nature of the soil, and the beauty of the islands in Lake Huron. This is a potential resort site.

PLATE XXV

FIG. 1. Typical forest cover in the Stony District. Here, as well as in the Transitional District, practically the only exports are such forest products as pulpwood, posts, poles, ties, bolts and piling.

FIG. 2. Farm development in the Stony District. The difficulty of cultivation here is apparent. The county would be much more wealthy if this land was covered with the forest shown in the background.

PLATE XXVI

FIG. 1. The U. S. Post-office at Maxton, Michigan. The postmaster comes twice a week. This post-office is 65 miles from the nearest railroad and all mail passes over four stage-routes to get there. This is an example of the isolation of the greater part of the Stony District.

FIG. 2. A view on the Sandy Pine Plains. A thick stand of jack pine in the background. Jack pine reproduction after a fire in the foreground. Blueberries are extremely plentiful on such land the second year after fire. The blueberry crop brings an income of $125,000 yearly to the pickers or about one third of the value of all dairy products sold in the county.

FIG. 3. Sandy Pine Plains that have been burned and reburned until there is no forest reproduction. This is an example of the land that has reverted to the state for non-payment of taxes, or land that is being planted to pine by the Federal Government.

PLATE XX

FIG. 1

FIG. 2

PLATE XXI

FIG. 1

FIG. 2

PLATE XXII

FIG. 1

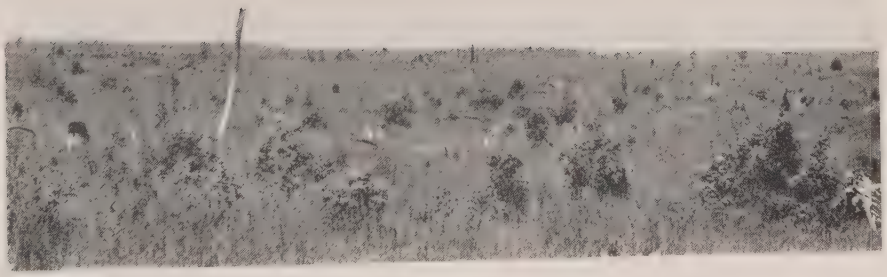


FIG. 2

PLATE XXIII

FIG. 1

FIG. 2

PLATE XXIV

FIG. 1

FIG. 2

PLATE XXV

FIG. 1

FIG. 2

FIG. 1

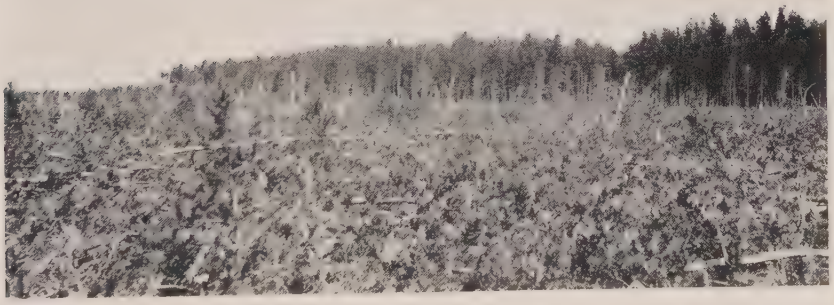


FIG. 2

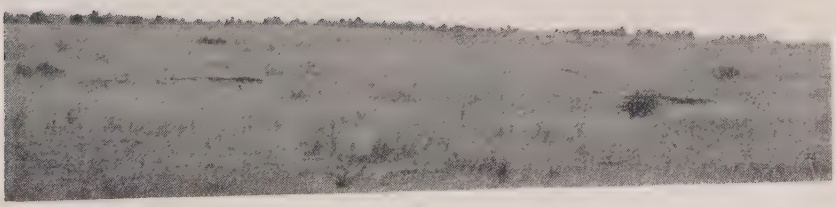


FIG. 3

THE DRY PRAIRIES OF MICHIGAN

JETHRO OTTO VEATCH

THE pioneers and early settlers in Michigan applied the term *prairie* to treeless bodies of land, but did not everywhere make a distinction between relatively dry grassland on the one hand and marsh on the other. The *dry* prairies constitute the subject of this paper. These natural features possess considerable local historic, physiographic, geographic, pedologic and ecologic interest. This article is presented from the point of view of the pedologist, or soil scientist, as a contribution to the geography of the state.

Location and size. — The prairies are restricted to the southwestern part of the state (see sketch maps, Figs. 20–21). They occur as small, separate bodies, varying in size from about 80 acres to a maximum of about 25 square miles. A total of 39 have been located.

Physiography. — In topography all the land is level or has only a slight slope or very gentle roll. Some of the larger bodies include shallow depressions or basins which either may be dry or may contain lakes and peat deposits. Since the drainage is largely subterranean, there has been practically no stream-cutting. In one place, namely, Grand Prairie west of Kalamazoo, there has been a small amount of gullying on the edge of the prairie adjacent to the river valley escarpment, and also on the Big Prairie in Newaygo County wind-erosion has disturbed the original surface.

All the prairies occur on glacial outwash or on the coarse valley filling in old glacial drainageways. The geologic deposits underlying appear to be the same or very similar in origin, and in mechanical composition and structure, in that they are glacial outwash or valley filling, are relatively coarse sand or gravel or both, unconsolidated and pervious. The deposits vary slightly

locally in lithologic composition, for example, in the relative proportion of some one kind of rock as shale or limestone, but in general the deposits are heterogeneous, since they contain a variety of both crystalline and sedimentary rocks. In geologic

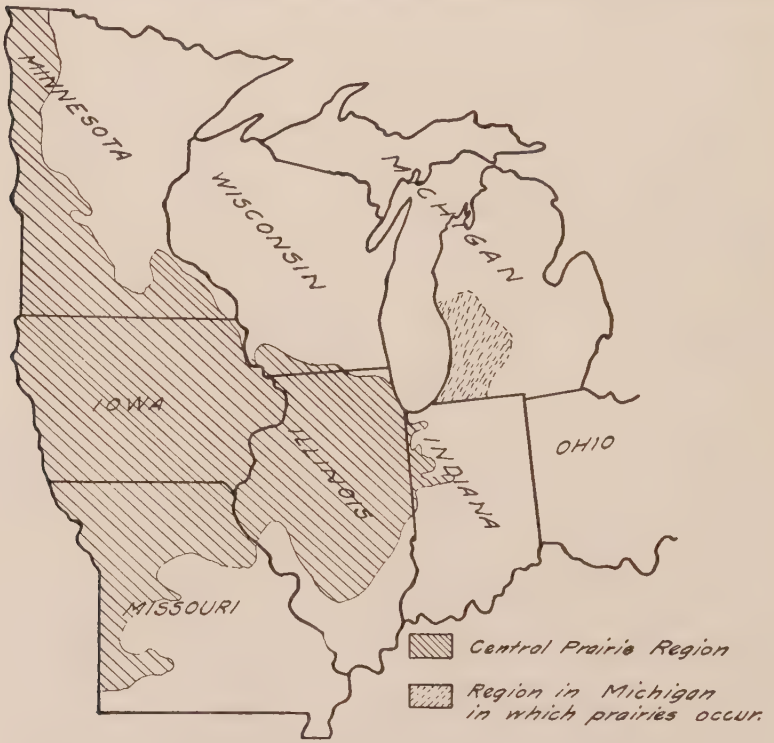


FIG. 20. Location of the prairies of Michigan with reference to the central prairie region of the United States

age, the deposits belong presumably to the Wisconsin stage of the Pleistocene.

There appears to be no consistent difference in elevation with reference to contiguous forest land on the plains. But where a prairie borders a moraine or a swamp, as in a few places, the forest may be higher or lower. The general elevation of the plains above sea-level is approximately 800 to 900 feet.

In brief, there appears to be no marked difference in topography and geology from the adjacent forest land on the outwash plains, although some slight differences in the lithologic composition of the underlying deposits may exist.

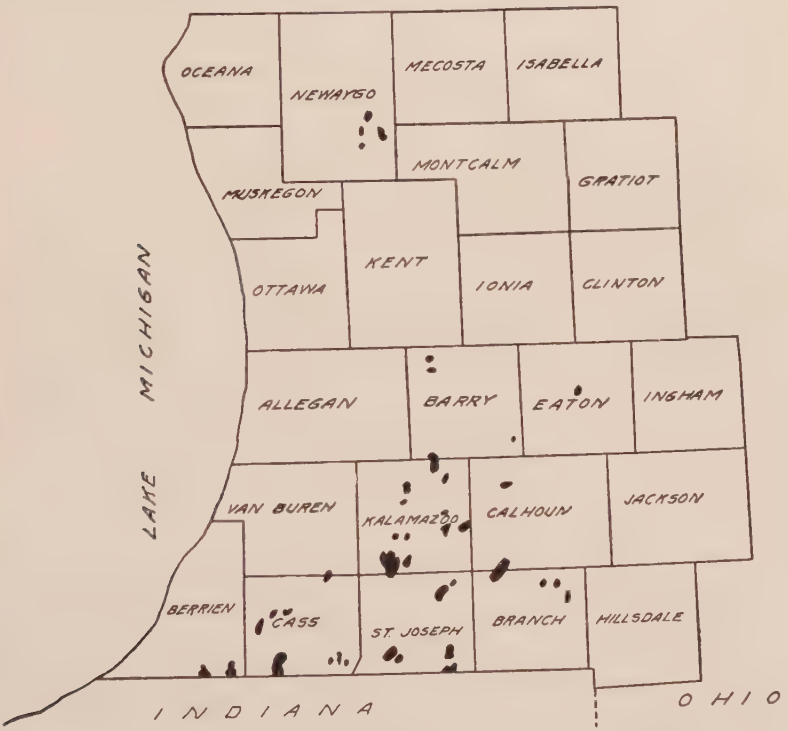


Fig. 21. Map showing distribution of prairies in Michigan

Vegetation. — There were a few burr oak (*Quercus macrocarpa*, Pl. XXVII) on nearly all the prairies and some hazel brush, particularly on the forest border. No complete list of the species occurring in the original herbaceous cover can be given. The land was broken up for farming at an early period and it is fairly certain that no virgin prairie land exists at present. We can safely assume, from the accounts of early settlers, that the grass formed a sod and was tall. Probably the chief genus was Andropogon.

The following list of species on the prairies was given by Dr. Beal: [1]

Amorpha canescens Pursh.
Asclepias verticillata L.
Atheropogon curtipendulus (Michx.) Fourn.
Bouteloua curtipendula (Michx.) Torr.
Baptisia leucantha Torr. and Gray.
Coreopsis palmata Nutt.
Echinacea purpurea Moench.
Helianthus rigidus Desf.
Phlox bifida Beck.
Silphium spp.

Climate. — The prairies occur in a region of 32 to 36 inches annual precipitation and 46 to 49 degrees Fahrenheit, mean temperature. The precipitation is fairly evenly distributed, but is slightly greater in May, June and July.

Soils. — The soil of all the prairies has a darker color than the surface horizon of the well-drained mineral soils of the forest, a higher content of humus and coloring from humus to greater depths. The soils of all the prairies, with one exception, have the same profile and belong to one series or group in the technical classification. A number of separate phases, however, can be recognized, based upon slight textural variations and variations in thickness of separate horizons. The generalized soil profile is as follows:

1. Surface horizon, dark brown; organic matter in very fine state of division and humified; granular-loamy in consistency; thickness, 6 to 20 inches.

2. Gradational horizon, lighter shade of brown than No. 1; granular, friable; thickness, 3 to 10 inches.

3. Yellowish-brown to reddish-brown, very compact clayey horizon; thickness, 4 to 20 inches.

4. Sand and gravel, unconsolidated; pervious and relatively dry or low in moisture.

Horizons 1 and 2 range in texture from sandy loam to silt loam; the content of organic matter in Horizon 1 is generally

[1] Beal, W. J., *Michigan Flora*, Prepared for the thirtieth annual report of the State Board of Agriculture, 1904, p. 19.

about 3 to 4 per cent. Horizon 3 probably nowhere contains more than 20 to 25 per cent of clay and includes considerable coarse matter, which may be in places of gravel size, but becomes very compact under certain conditions, so much so that it is referred to locally as "hard pan." The colloidal or clay matter present is strongly cohesive or adhesive and possesses very high tensile strength upon drying. Horizon 4 consists of unaltered or but slightly altered parent material and is composed of stratified or water-assorted sand and gravel, with cobbles in places. The depth of appreciable alteration by weathering or soil-forming agencies is 30 to 40 inches. The soil holds only relatively small amounts of water, but slightly higher than the associated forested sands. The upper part of the substratum is dry or very low in moisture and the water-table lies generally at depths greater than 8 or 10 feet. The whole profile is penetrable and roots of trees and shrubs, alfalfa, or sweet clover penetrate to and into the sand and gravel of Horizon 4, while the roots of blue grass penetrate well into Horizon 3.

Chemical analyses reveal no unusual or abnormal peculiarities in composition. The organic matter and nitrogen are somewhat higher for the same thickness as compared with forested soils; the amounts of lime, magnesium, phosphorus, potash, sodium, iron and aluminum are not different from those of originally forested soils of similar texture throughout southern Michigan. An analysis of a representative soil from Portage Prairie, Berrien County, follows:

Analysis * of Prairie Soil, Berrien County, Michigan

	Horizon 1	Horizon 2	Horizon 3	Horizon 4
H_2O	1.98	1.30	1.82	0.38
Ignition loss	10.33	5.16	5.70	1.89
SiO_2	74.60	77.40	76.85	87.01
CaO	1.73	1.85	1.78	1.85
MgO	1.95	2.03	2.10	1.43
K_2O	1.82	2.00	1.94	1.54
Na_2O	1.30	1.22	1.12	1.14
Fe_2O_3	2.10	2.80	3.65	2.50
Al_2O_3	1.85	5.18	4.48	2.08
TiO_2	0.28	0.48	0.53	0.45
P_2O_5	0.22	0.12	0.09	0.05
MnO	0.15	0.12	0.31	0.08
SO_3	0.62	0.08	0.05	0.09
Total	98.93	99.74	100.42	100.49
CO_2	1.87		0.07	0.15
N	0.21	0.08	0.05	0.02

* The analysis is quoted from a paper by M. M. McCool, J. O. Veatch and C. H. Spurway, "Soil Profile Studies in Michigan," *Soil Science*, 16: 100.

The surface horizon is strongly to very strongly acid in reaction according to hydrogen electrode measurements and field-tests with Soiltex; Horizon 2 is strongly acid; Horizon 3, strongly acid in the clay part, but some of the coarse matter is basic; the substratum, or Horizon 4, is calcareous, or aklaline, owing to coarse particles of limestone and incrustatious calcium carbonate as a secondary deposition.

The profile of a forested soil associated with the prairie is given for comparison (see sketch, Fig. 22):

1. Surface horizon, leaf litter and mold;
2. Light brown, humous soil, thickness 2 to 4 inches;
3. Gray to yellow leached horizon, 6 to 15 inches;
4. Compact clayey horizon, yellowish to reddish-brown, in places red when moist, thickness 6 to 15 inches;
5. Sand and gravel, unconsolidated, pervious, dry.

The most marked difference in the profiles is in the organic matter in the surface horizons; otherwise they seem to be simi-

lar chemically and physically and in profile arrangement. It appears from observation that there may be slightly more compaction in the B or clay horizon of the prairie soil, although convincing quantitative proof of this is lacking.

The prairie soils, according to the scheme of classification

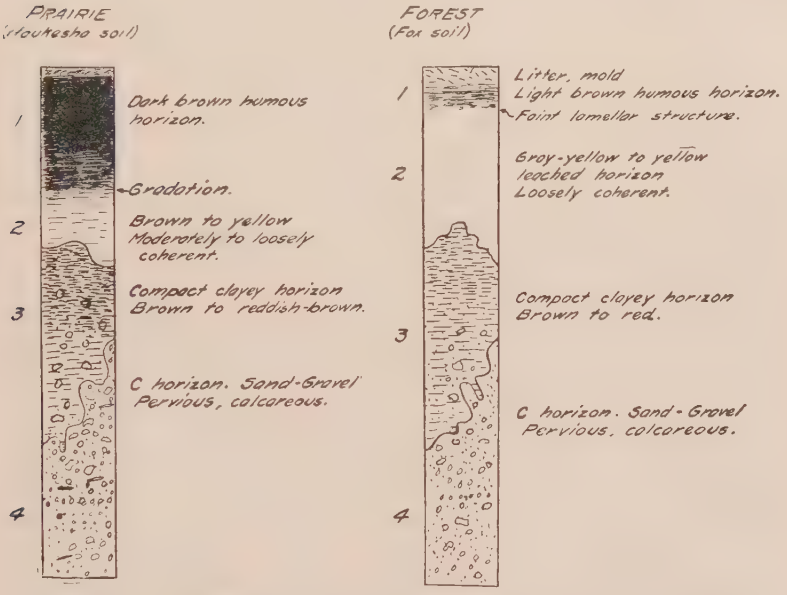


FIG. 22. Comparison of profiles of prairie and forest soils, Michigan

adopted by the United States Bureau of Soils, are classified as Waukesha (Warsaw) types and the analogous forest soils as Fox types.

The soils of the Michigan prairies, compared with those of the subhumid prairie regions of Illinois, Iowa and Missouri, have in common a dark brown or blackish color, and high humus and nitrogen content to relatively great depths. There are also small bodies of the same type of soil, but most of the types in the prairie region to the west show marked differences, such as a high lime or non-acid condition at the surface, much heavier texture throughout the profile, and higher fertility.

The soils of the Big Prairie of Newaygo County constitute a single exception to the description of the Michigan soils just given. Here the dark color is present at the surface, but the texture is sand throughout the profile.

Geographic influence. — The prairies comprise a total of about 80,000 acres and this is distributed in separate small bodies. They have, therefore, not exerted any great influence on the trend of settlement or upon the character of the people and industries in the state. The prairies attracted the pioneers, who began making permanent homes in southwestern Michigan about 1825–30, because the land could be plowed immediately and did not require so laborious effort for reclamation as did the forest land. The land had an advantage in being level, and was therefore prized, so that it was all occupied at an early date. It was well adapted for wheat and this crop was grown continuously year after year in many places, as was true on the prairies farther west. The level topography and easy tilth favored rather large fields and farms and these have remained to the present time. In fertility and productiveness the prairie soil is considered to be intermediate, being somewhat higher than the forested sands and rolling sandy loams, and less than the forested more level clay soils of this region. Lack of sufficient moisture at critical periods in crop growth is probably the chief limiting factor in the production of very high yields. Relatively, the land probably had a higher agricultural value fifty to seventy-five years ago than at the present time.

There are no large cities and the towns and villages located on the prairies, such as Schoolcraft, Climax, Girard and Richland, are probably no larger or more important than forty or fifty years ago. The city of Charlotte in Eaton County is supposed to occupy a prairie, but there is no evidence of any prairie soil outside the city limits, and the land otherwise is so completely occupied that it is not possible to make satisfactory comparisons with other bodies.

Practically all the prairie land is in use at the present time for agricultural purposes, except the Big Prairie in Newaygo County, which was originally productive but at the present time is largely abandoned because of wind-erosion.

Origin. — Observations on the soil support a theory that the prairies were naturally treeless and not treeless primarily because of fires. The humus of the surface horizon of the soil appears to be derived entirely from the organic matter of herbaceous plants, while the thickness of the humus horizon indicates age. In pedologic terminology the soil is *mature.* In a great number of detailed profile descriptions, I find no evidence of a degraded forest soil, no suggestion of the grayish or pale yellowish highly leached horizon characteristic of forested acid mineral soils of this region.

The profile indicates further that the soil developed under conditions of intermediate or relatively low moisture — moderate average, but variable soil moisture in the surface, relatively low though more uniform in the B horizon, and very low in the C, beginning at depths of 2 to 3 feet. There is no evidence remaining of the peculiarities common to excessive moisture or waterlogging if these conditions ever existed.

The prairies are assumed to be relicts of grassland which was a part of the great subhumid prairie region of the Mississippi Valley. It is conceivable that the whole region of southern Michigan was treeless immediately after the retreat of the ice-sheet. The soil or geologic formations differed and on some sites conditions were more favorable for an early occupation by forest than on others. The climate could hardly have been different on present forested and unforested sites. There is no evidence to support a contention that some chemical condition in the prairie soil inhibits tree growth. On the contrary, trees grow when planted, and there is abundant evidence that the forest has been rapidly encroaching under natural conditions. Incidentally the soil profile affords a means of estimating the time since contiguous lands have been forested, inasmuch as the thickness and color of the A 2 horizon may be taken as a criterion.

In this region loam and silt loam types underlain by clay in the B and C horizons, such as the Miami and Brookston, possess sufficient moisture and fertility to support both grass and tree growth. At the other extreme, on the driest and least fertile soils, such as the Plainfield, subject to shifting by wind action,

the physical conditions were unfavorable for a complete cover or sod of herbaceous vegetation, and therefore trees could obtain a foothold. An intermediate condition, particularly in relation to moisture and a loam or silt loam texture, would appear to have been most favorable for grass. Such a condition is found on hilly or rolling types of soil, but these have been forested for a great period of time. Slopes, however, favor wind- and water-erosion, and stones on the surface present conditions favorable for trees and shrubs in competition with grasses. A moderately dry soil, therefore, level in topography, loamy or silty in the surface, would be most favorable for grass under the condition of climate prevailing.

Michigan State College
East Lansing, Michigan

PRAIRIE NEAR ATHENS, MICHIGAN. BURR OAK WERE PRESENT ON THE VIRGIN LAND

SOME ASPECTS OF MARL DEPOSITS IN OCEANA COUNTY

STANARD G. BERGQUIST

OCEANA COUNTY is typically an area of sandy soil, made up largely of outwash and till plains. Approximately eighty per cent of the surface area is light and sandy in character and the remaining twenty per cent about equally divided between lowland swampy areas, including lakes, clayey till and gravelly loam.

The marl is quite widely distributed through the county although in some of the townships, especially those in which the soils are uniformly and persistently light in texture, no trace of marl is to be found.

The deposits of marl in the county are of two distinctively different types and for the sake of convenience I have tentatively classified them into two groups, based upon their relationship to the water table, namely, lowland and upland deposits.

LOWLAND MARLS

(See Plate XXVIII)

The lowland types are by far the more common and make up the greater proportion of the deposits in Oceana County. They occur in beds of variable thickness in swamps and marshes, in river beds and as marginal deposits in lakes.

The marl in these areas is generally found below the normal water table and in such positions as to be constantly saturated with water. The thickness of the beds ranges from a few inches to twenty and more feet, depending to a large extent upon the size of the depression in which the material was allowed to accumulate.

The lowland marl beds are usually mantled with a layer of muck and peat which in many of the swamps and decadent lakes has accumulated to rather extensive depths, indicating that quite a long period has lapsed since the cessation of marl-forming activities. In some areas, however, marl is still in the process of formation and is accumulating more rapidly than is the encroaching vegetation, which in time will undoubtedly form a layer of organic matter to seal up completely the deposit and prevent further deposition of marl.

The marls of this type are extremely variable in color and in quality. The purer forms are as a rule grayish but, where intercalated with vegetal remains in the form of muck and peat, they generally assume a darker shade. The color of marl is not always an index of its quality, although it is unquestionably true that those of lighter colors contain less organic matter of vegetable origin, and hence would be likely to have a higher percentage of calcium carbonate than those that run darker. In some of the darker marls, however, those which apparently were contaminated with muck and peat, the final analysis showed a relatively high content of lime.

The waterlogged marls are heavy and difficult to handle. When freshly dug they contain water to approximately half of their weight and are frequently pasty or mushy in character. If intermixed with clayey material, they are plastic and sticky. When they dry, a large amount of water is released and the color becomes considerably lighter, oftentimes pure white. A cubic foot of marl taken from the borders of McLaren's Lake was weighed immediately after its removal from the water and found to weigh 104.8 pounds. A cubic yard of this material, completely saturated with water, would accordingly weigh 2829.6 pounds.

In the deeper layers of the saturated deposits and particularly where the marl is of a colloidal nature, the presence of hydrogen sulfide seems to be quite apparent, both in the lake and marsh deposits. This substance is readily detected by its odor when present in large quantities and will frequently produce a purplish tarnish on a brass rod even if in only limited association with the marl.

Marl which has formed and developed completely under water is generally not fit to be applied directly to the soil immediately upon being dug. It should be piled up in small heaps and allowed to weather thoroughly. The process of drying tends to remove a large proportion of the water and allows the included toxins to escape. At the same time the marl is rendered more friable and made easier to apply and also more useful as a soil-builder. If piled up in large deposits on the surface, the material weathers very slowly, and ordinarily only in the outer portions. On the inside it remains quite unchanged as to moisture content and textural properties.

UPLAND MARLS

(See Plate XXIX, Figures 1 and 2)

The upland areas of marl are somewhat more limited in their distribution, but nevertheless constitute beds of great importance in the county. They are found in the terraces of lakes, where the water level has subsided, and in the upper flats, terraces and old meander channels of streams and rivers.

The marl in these deposits is largely concentrated in beds that lie above the present normal water-table. They are for the most part fairly dry as compared with the lowland types. In seasons of excessive rainfall, however, the water-table rises, very frequently to levels above the surface of the deposits. In general the beds are relatively shallow, seldom, if ever, attaining a thickness exceeding six or seven feet; they would probably average three to four feet thick for the county.

The surface cover ordinarily is so thin as to be practically negligible. It consists merely of a few inches of muck, more often up to six or eight inches of wind-drifted sand. Occasionally, thin lenses of sand are found scattered through the marl beds, but not in quantity sufficient to be of serious consequence in the economic handling of the deposits.

The upland marls are predominantly grayish to whitish. In deposits where clay forms the substratum and prevents proper drainage, they are frequently mottled with brown. As a general rule the marl of this type is fairly pure and runs high in calcium

carbonate content. Very little muck or peat is interassociated with it.

Inasmuch as the deposits lie above the normal level of the ground waters, the marl is comparatively light in weight. A cubic foot of the material was dug from the dry bed on Carlton Creek and found to weigh 56.8 pounds, that is, 1533.6 pounds per cubic yard. Another sample, taken from the flood-plain terrace of Cushman Creek, weighed 85.1 pounds per cubic foot or the equivalent of 2297.7 pounds to the cubic yard.

The upland marl is characteristically friable in texture and breaks readily into a crumb structure upon weathering. Because of its relatively porous nature and exposure to weathering activities, it is quite commonly completely aërated and requires little or no preliminary curing to be used on the soil. In several areas, especially where the marl was colloidal and the base of the deposit rested in the upper ground waters, the odor of hydrogen sulfide was very apparent.

ECOLOGICAL CONSIDERATIONS

There seems to be a rather definite relationship between marl deposits and plant associations. In the southern part of the state, a variety of Potentilla grows luxuriantly in areas where marl is present. In fact, the presence of this plant may be reliably used as a positive indicator of marl. In Oceana County not a single trace of the plant was found, although in the adjoining county of Newaygo it was present in merely one isolated area of the six townships surveyed.

If we are to differentiate between bog and marsh in reference to character of soil and type of vegetation present, it will be quite necessary to make some changes in the nomenclature of marl deposits. If we define a marsh as an area of low-lying, swampy land with soil of an alkaline character and supporting vegetation with alkaline requirements, and then contrast the bog as having an acidic soil and favoring a growth of vegetation with acidic tendencies, it is no longer correct to classify marls in the category of bog limes, as has been done in the past.

Marls do not form under bog conditions although it would be

possible for a bog to become the site for marl deposition through a change in drainage conditions. If the ground waters, flowing through the soil containing nodules and concretions of limestone, were diverted from their courses so as to carry lime carbonates into a bog, conditions might then be made favorable to marl-forming processes. With the neutralization of the heretofore acid waters of the bog, lime-secreting plants and animals would undoubtedly come in and assist further in marl accumulation.

Of the bog types of plants found in Oceana County, two are especially outstanding in their complete aversion to marl. Wherever Cassandra (see Pl. XXIX, Fig. 3) and Andromeda grow, marl will not be found even with depth. Bogs with these plant types are numerous in the sandy plains of the county and occasionally also in the areas where the heavier types of soil have developed under conditions of improper drainage. Soiltex tests made in these bogs and also in the soils of the higher surrounding areas always revealed an acid character of soil.

It is natural, of course, to expect that acid bogs should be developed in regions where the ground waters flowing into them have their origin in glacial deposits containing soil of an acid nature. It seems probable that the environmental conditions are the factors which would determine whether lowland areas will develop into marshes or bogs. The type of vegetation which would come into the depression would be influenced largely by the conditions existing in the watershed area of the basin.

Sphagnum moss occurs in lowland habitats and almost always in acidic associations. Occasionally, thin beds of marl are present in the sphagnum-floored depressions, but generally below a thick mantle of muck and peat.

Tamaracks and cedars grow under variable conditions and their presence in the swamps is never a positive index to the occurrence of marl.

Along the lake borders, the growth of Chara and Potomogeton always seems to indicate areas in which marl is in process of accumulation. On the other hand, in regions where lily pads and cat-tails form the bulk of the vegetation, muck and peat with scarcely any marl characterize the deposit.

From observations made in a large number of deposits during the summer of 1926 I am somewhat inclined to discount the importance of Chara as a factor in the formation of thick deposits of marl. It is obvious that Chara is a lime-secreting plant and functions to a certain degree in the accumulation of marl, but many other plants are of equal importance in this respect. Much of the marl, especially the extensive deposits, has formed through the accumulation of animal remains and also through the process of precipitation of calcium carbonate carried into the depressions by surface and ground waters.

Michigan State College
East Lansing, Michigan

EXPLANATION OF PLATES

PLATE XXVIII

Figs. 1–2. Lowland areas of marl deposits. The marl in these beds has a thickness exceeding twenty feet and is covered with a mantle of twelve to sixteen inches of muck and peat. The water-table is above the surface of the marl

PLATE XXIX

Figs. 1–2. Upland areas of marl deposits. Terraces of marl a quarter of a mile back from the present stream. The beds contain marl to a depth of six feet and are covered with a few inches of wind-drifted sand

Fig. 3. A Cassandra bog

PLATE XXVIII

FIG. 1

FIG. 2

FIG. 1

FIG. 2

FIG. 3

THE PROGRESS OF REPLACEMENT AND THE FORMATION OF CONCRETIONS

CHARLES W. COOK

THE problem of the replacement of fragments of rock by the action of mineral-bearing solutions and of its effect upon the shape of the replaced fragment has received considerable attention in recent years. Spurr [1] has emphasized the significance of angular fragments in supporting his theory of ore magmas, while Bateman [2] has shown that angular fragments may be formed by replacement.

Another closely related problem, which has also been the subject of debate among geologists, is the formation of nodules or concretions in shales and sandstones. The preponderance of opinion apparently has favored the theory of a segregation around an original nucleus.

A third problem has to do with the rôle of diffusion in causing the migration and segregation of minerals.

A specimen which the writer found near Silver Camp, Lewis and Clark County, Montana, appears to offer possibilities of shedding some light on all three of these problems.

DESCRIPTION OF THE SPECIMEN

The specimen to be described (see Plate XXX, Fig. 1) is a cleavage fragment of arenaceous slate or quartzitic schist of pre-Cambrian age. Its general color is yellowish to buff, upon which background is superimposed the red color of the "rings" which it is the purpose of this paper to discuss.

The fragment possesses a pseudo-hexagonal outline and measures from five and a half to six inches between opposite

[1] Spurr, J. E., *Ore Magmas*, New York. 1923.
[2] Bateman, Alan M., *Econ. Geol.*, 19: 504–20. 1924.

angles and approximately three eighths of an inch in thickness. The pseudo-hexagonal outline of the fragment is suggestive of hexagonal jointing resulting from contraction. I do not believe, however, that the hexagonal outline is more than a coincidence, as it does not seem possible that original mud cracks could have persisted during the metamorphism to which the rock has been subjected. Furthermore, the joint planes make different angles with the plane of schistosity. For example, the angle between the joint plane *a* (Fig. 23) and the plane of schistosity is 90 degrees, whereas the angle between *b* and the plane of schistosity is 70 degrees. There are apparently three sets of joints, indicated in Figure 23 by *a*, *b*, and *c*, sets *a* and *b* making an angle of approximately 45 degrees with each other; and *b* and *c*, 35 degrees, thus accounting for the pseudo-hexagonal outline.

The "rings" which are due to segregations of hematite are the feature of most striking interest in the specimen. These may be seen in Plate XXX, Fig. 1, which is a photograph of the specimen or perhaps better in Figure 23 which is a rather accurate drawing of the specimen, in which the shaded portions represent the red color of the hematite, the heavier shading representing the more intense color. The features of the "rings" to which I wish to direct attention are: (1) the tendency to follow the joint form in the outer "rings"; (2) the tendency to assume an elliptical form in the central portion; (3) the fact that the inner margin of the outer broad band conforms to the angularity of the fragment more closely than does the outer margin of the band; and (4) the banded or zonal distribution of the hematite, giving the appearance of Liesgang rings. It should also be pointed out that these "rings" are not a surface feature, as they are observable on both sides of the fragment. Plate XXX, Fig. 2, is a photograph of the reverse side of the fragment, the surface of which has been produced by grinding in order to prove definitely that the "rings" are not a surface feature.

ORIGIN OF THE "RINGS"

In attempting a satisfactory solution of the problem of the origin of the "rings," the normal method would be to determine

first the source of the iron. Was the iron originally present in the rock and subsequently segregated into the "rings," or has it been introduced from the outside by circulating waters? If the iron was originally present, have the "rings" been formed by the segregation of disseminated iron compounds or by rearrangement of preëxisting concentrations?

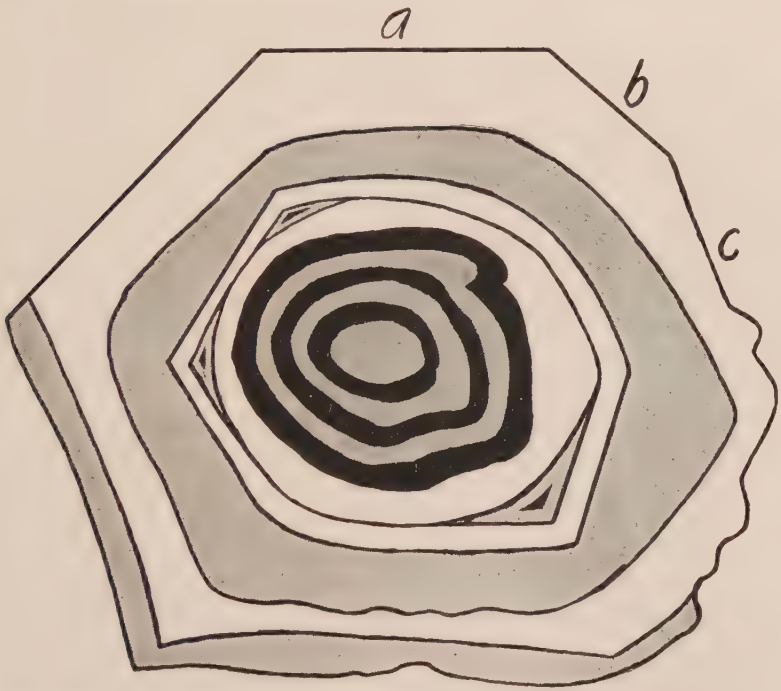


Fig. 23. A line-drawing of the fragment shown in Plate XXX, Fig. 1. The degree of shading indicates the intensity of the iron coloration of the "rings."

The slates of the area are for the most part gray to blue to black, becoming yellowish to buff on weathering and therefore indicating the possible presence of iron compounds, but scarcely in sufficient amounts to account for the amount of hematite which has been concentrated in the specimen. The possibility that this represents a rearrangement of an original concentration,

such as a pyrite nodule or ironstone concretion, in the premetamorphic rock, does not receive much support from field evidence. No such concretions were found in the rocks from which the specimen was obtained. Although this does not disprove the former presence of iron concretions, it does cast doubt upon it. Further the writer is unable to account for the fact that the inner margin of the outer band conforms more closely to the shape of the fragment than does the outer margin, on the basis of an original iron concretion, the iron of which has been subjected to disseminating action by solutions. Moreover such action is contrary to the general tendency of solutions, which is toward concentration rather than dissemination.

As to the possibility of the iron having been introduced from an outside source, its segregation along the joints in the slate is suggestive, although this segregation may have occurred during weathering. The slates of the area have been intruded by both basic and acid igneous rocks and numerous veins and veinlets carrying metallic sulphides have been formed, those showing only pyrite predominating. This suggests a possible source for the iron-bearing solutions. It is to be concluded, therefore, that the evidence, although not definitely positive, favors an outside source.

If we assume that the iron has been introduced from an outside source by solutions circulating along the joint planes, what is the mechanics of its introduction into the fragment which will account for the phenomena shown by the "rings"? Since the iron is not concentrated along fractures in the slate fragment, it must have been introduced through capillary openings. And since the concentration has been toward a single point, concentration by circulating solutions could not have occurred. Therefore, the iron must have been introduced by diffusion from the solutions circulating along the joint planes.

If the iron were present in the joint solutions in the form of the ferrous salt, such as the ferrous bicarbonate, oxidation, either before or after deposition, would be necessary in order to give the hematite "rings." Since there is no evidence of an oxidizing agent which might have caused the iron to be deposited in the

ferric form originally, the oxidation of the iron, if it occurred, would most likely have been subsequent to the original deposition. There is no evidence that such subsequent oxidation has occurred.

As already mentioned, there is evidence in the district of the deposition of pyrite from solutions probably of magmatic origin. Becker,[3] Doelter [4] and others have stated that pyrite may be transported in the form of the sulphide in solutions of alkali carbonates and sulphides containing an excess of carbon dioxide. According to Stokes,[5] the following reversible reaction is possible:

$$8\,FeS_2 + Na_2CO_3 = 4\,Fe_2O_3 + 14\,Na_2S + Na_2S_2O_3 + 15\,CO_2.$$

Since this is a reversible reaction, the direction in which it will proceed is dependent upon the addition or abstraction of compounds from the system and possibly upon temperature changes.

As already indicated the evidence points to the fact that the iron could have been introduced only by diffusion. Therefore the other substances in solution with the iron would likewise diffuse from the joint openings into the fragment. Since the rate of diffusion differs with both the substance and the concentration of the substance, at a given distance from the point of diffusion the ratio of the dissolved substances would be changed. This might result in supersaturation with respect to certain compounds, a reversal of the reaction, and the precipitation of hematite.

The precipitation of hematite would be accompanied by the formation of sodium sulphide, which would pass into solution, and the liberation of carbon dioxide which would tend to dissolve the silica, thus permitting its replacement by iron. The points at which the precipitation would occur should tend to form a line parallel to the joint planes. From this line the sodium sulphide liberated would diffuse both toward the joint planes and toward the center of the fragment. That portion of the sodium sulphide diffusing toward the joint planes would tend, first, to decrease the diffusion of the sodium sulphide from the solution in the

[3] Becker, G. F., *U. S. G. S.*, Mon. 13, p. 432, 1888; also *Am. Journ. Sci.*, 3d ser., 33: 208.

[4] Doelter, C., *Tschermaks Min. Mitheil.*, 11: 324.

[5] Stokes, H. N., statement by Van Hise, C. R., *U. S. G. S.*, Mon. 47, p. 1127. 1904.

joint plane, and secondly, to stop the precipitation of the hematite or even to dissolve some of the hematite already precipitated. That portion of the sodium sulphide which would diffuse toward the center of the fragment while the hematite was being precipitated would be establishing conditions unfavorable to the deposition of hematite, so that the iron would pass through a certain zone before supersaturation would again develop and a second deposition of hematite occur. This process would be repeated periodically with a narrowing of the zones of deposition and non-deposition until the center of the fragment was reached, the zones tending to become elliptical because of the elongation of the fragment and the increasing distance from the influence of the joint-form. Since certain cleavage planes would function as circulation channels in the plane approximately at right angles to the joint planes and since the spacing of these would tend to be greater or less than the spacing of the joint planes, the resulting depositional form would be either elongated or flattened in this dimension.

The phenomenon of rhythmic banding, known as Liesgang [6] rings, which the "rings" in this fragment suggest, has been shown experimentally to occur when an electrolyte penetrates a gel and precipitation takes place. Ostwald [7] suggested that this is due to recurrent periods of supersaturation. More recently Bradford [8] has advocated the theory that the rings are adsorption phenomena and has opposed the supersaturation theory. All the experiments in connection with this rhythmic banding have been carried on in the presence of colloids and the implication is that the phenomena are related to colloids. In the case under discussion there is no evidence of the presence of colloids. For that reason the phenomena have been explained on the basis of reactions resulting from differential diffusion of substances in the same solution which give rise to recurrent periods of supersaturation. In the experimental work the reacting substances have been introduced in different solutions, which have been brought

[6] Liesgang, R. E., *Geologische Diffusionen*, Dresden. 1913.
[7] Ostwald, W., *Lehrbuch der Allgemeinen Chemie*, 2: 777–780. 1902.
[8] Bradford, S. C., *Biochem. Journ.*, 14: 474. 1920.

into contact by diffusion through a colloid gel. May it not be the case that the action is not a phenomenon specifically related to colloids, but that they supply conditions which make possible the use of stronger solutions and shorter periods of time than is necessary in the case of geological phenomena?

In his monograph on the Ray and Miami, Arizona districts, Ransome [9] shows an excellent example of the "rings" in a quartzite. As to the origin, he believes that they have been formed during weathering and says: [10] "The coloring matter of the concentric rings is iron oxide, and the pattern was apparently produced by rhythmic alternations of solution and precipitation of the iron along joints in the quartzite." No reasons for these assumptions are given.

CONCLUSIONS

From a consideration of the facts and interpretations presented, it may be concluded that:

1. In the replacement of fragments by circulating solutions, the action may begin at some point within the fragment rather than at the margins, if the primary chemical reactions involved take place between compounds all of which are in solution, instead of occurring at the contact between the solutions and the wall rock.

2. When the replacement is of this type, the reaction begins at the point at which the distance from the source of the diffusing substances is sufficient to permit diffusion so to change the composition of the solution that precipitation will occur.

3. The extent to which the original form influences the shape of the replaced fragment is a function of the distance from the margin at which the reaction takes place and the angles between the faces of the fragment. That is to say, if precipitation occurs before the lines of diffusing ions from different faces meet, the deposit will tend to take the form of the fragment. Beyond that point the tendency is to produce a spherical form The resulting form, however, will generally be that of an oblate ellipsoid, since the fragment will rarely be a perfect cube.

[9] Ransome, F. L., *U. S. G. S., Prof. Paper 115*, Plate XIV. 1919.
[10] *Ibid.*, p. 45.

4. Concretions do not necessarily represent segregations of minerals around an original nucleus, but may result from the rhythmic deposition of minerals, the constituents of which have diffused from solutions in joints and bedding planes, the shape of the concretions being determined by the spacing of these planes.

5. An apparent nucleus may represent merely an unreplaced portion of the original rock.

6. In a specimen in which segregation around a nucleus has occurred, the nucleus itself may have been formed first by segregations due to differential diffusion of reacting substances in the same solution.

University of Michigan

PLATE XXX

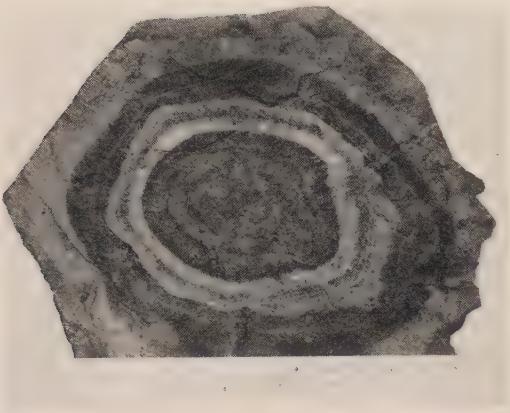


FIG. 1

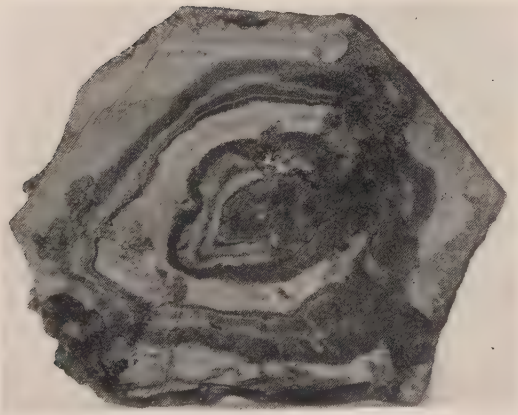


FIG. 2

THE CARBONIFEROUS FAUNA OF GRAND LEDGE

WILLIAM A. KELLY

IN THE spring of 1926 Professor S. G. Bergquist and I discovered a few marine fossils in an outcrop on the right bank of the Grand River just below the railroad bridge. The small collection made at that time was augmented by later collections from what appears to be the identical horizon exposed in the Briggs quarry, a short distance downstream from the place of original discovery. To date no systematic search has been made for fossils, but the results of several collecting trips in the past promise a comparatively large marine fauna. Although the outcrops at Grand Ledge are mentioned in some of the reports issued by the Michigan Geological Survey, I have not seen any references to a fauna consisting of more than a few forms. The preliminary study I have been able to give to the fauna has produced very few results, other than to show that a marine invertebrate fauna, consisting of at least a dozen species, is present. In the hope, however, that helpful suggestions for further study may be received, and also because of the interest that a new occurrence of Carboniferous fossils in Michigan may have, I am presenting what information I have been able to obtain.

There are two fossiliferous horizons containing marine faunas represented in the vicinity of Grand Ledge. The lower horizon, a dark, compact shale, is found on the south side of the Grand, in the bottom of a quarry worked by the Grand Ledge Clay Products Co. The only fossil I have found there is a species of *Lingula*, which appears to satisfy the written description of *L. umbonata* Cox given in the Thirteenth Annual Report for Indiana, Part II, p. 120, although it does not agree very closely with the plate figure of that species given in the same report.

The higher, and more interesting horizon, occurs on the north

side of the river in the localities mentioned previously. The fossils are in a bed of black, compact, calcareous shale, interbedded with fissile shales. The fauna is made up principally of brachiopods, which are generally rather poorly preserved, the preservation in some instances being by pyritic replacement.

Thus far I have been able to identify the following forms:

A small cup coral
Crinoid stems
A ramose bryozoan
Echinoconchus (*Productus*) cf. *biseriatus* (H.)
Echinoconchus sp., undet.
Marginifera (*Productus*) cf. *muricata* (N. & P.)
Orthothetes cf. *crassus* M. & H.
Productus cora d'Orbigny
Productus cf. *costatus* (Sowerby)
Productus sp., undet.
Pustula (*Productus*) *nebraskensis* (Owen)
Schizophoria sp., undet.
Spirifer aff. cameratus Morton
Griffithides scitulus (M. & W.)

This list has an undoubtedly Pennsylvanian aspect. It is possible that a closer study of the fauna of Grand Ledge will enable one to make a much closer correlation, and to restrict the zone to a definite horizon. This will involve a more intensive study of the literature of this and adjoining states than I have been able to devote to it.

Thus far I have laid stress upon the species of the most common genus, namely *Productus*, and its subgenera *Echinoconchus*, *Marginifera* and *Pustula*. Of the fauna, *Productus prattenanus*, which Schuchert gives as a synonym for *P. cora*, is reported from the Lower Verne near Mercer by Lane.[1] *Marginifera muricata* is also reported from this horizon. I have been unable to secure a good description or plate figure of this form, and therefore cannot be sure of my identification.

In the vicinity of Owosso, a small fauna, including species of *Productus*, *Spirifer*, crinoid stems and *Zaphrentis*, as well as others not found at Grand Ledge, is reported by Rominger.[2]

[1] Lane, A. C., "Notes on the Geological Section of Michigan," *Report of the State Board of Geological Survey of Michigan for the Year 1908*, p. 88. 1909.

[2] Rominger, C., *Geology of Lower Peninsula*, Geol. Surv. Mich., Vol. III, Part I, p. 139. 1876.

The fossils there occur partly in calcified, partly in pyritous, condition, and are found in a black shaly lime rock. The description given of the Owosso occurrence might almost hold true for the Grand Ledge occurrence, and is suggestive of correlation, when the genera common to both localities are taken into account.

It will be noticed from the list of fossils that I have given that many of the species are compared with known species or are represented as undetermined. The resemblances in many specimens are very strong, and I do not expect that any new species will be described from the Grand Ledge fauna. In the identification of *Orthothetes crassus* there is a large element of doubt, since the form I have compared to it is represented only by outer molds, and the comparison has been based principally upon external ornamentation. *Productus cora* and *Marginifera muricata* are the two most common species. As stated before, I am uncertain of the identification of the second species. *Productus costatus* may not be present in the fauna. If it is, it is a form with finer costae than are usually associated with that species. The specimen of *Schizophoria* is represented by a fragment of a brachial valve and a few imprints of entire valves. The brachial valve is strongly ventricose and possesses a short hinge-line. The surface is covered by fine striations, crossed by a few concentric growth-lines near the lateral border. Distinct punctae can be seen on the striations. Only one specimen of a spire-bearer has been collected. It is imperfectly preserved, but suggests the fasciculate character of the plications characteristic of *S. cameratus*. The subclass, trilobita, is represented by a single pygidium. The nature of preservation is such, however, as to make identification fairly certain.

I have no doubt that the fauna of the upper marine horizon, which is represented today by fourteen species, will be increased when careful collecting is done. I think, too, that a comparison of this fauna with material available from other Carboniferous horizons, such as the one at Owosso, will reveal many forms in common and be a step toward the elucidation of the stratigraphy of the Pennsylvanian of Michigan.

Michigan State College
East Lansing, Michigan

GEOLOGIC STRUCTURE OF A SMALL AREA IN WAYNE, PULASKI AND RUSSELL COUNTIES, KENTUCKY*

DONALD C. MacLACHLAN

INTRODUCTION

Location and Size of Area

THE area discussed in this paper is in the south-central part of Kentucky and is that part of the northeast quarter of the Monticello Quadrangle situated north of an east-west line extending through Mill Springs on the Cumberland River. The area is reached most easily from Burnside, Kentucky, which is twelve miles northeast of Mill Springs and is the nearest railroad station. A motor bus line connecting Burnside with Monticello runs through Mill Springs and serves as a convenient means of reaching the area.

Purpose and Methods of Study

The purpose of the study was to determine the nature of minor geological structures in the area. To this end the top of the Chattanooga shale was selected as a key horizon. This selection was made because the Chattanooga shale is the one formation in the region that may be immediately and positively identified by its lithological characteristics, since contacts between it and the formations above and below it are very sharply defined, and since the outcrops are always at or near the bottoms of the creek beds where they are accessible for accurate instrument readings.

* The field equipment consisted of a government topographic map, a Brunton compass, a hand level and an aneroid barometer.

Detailed observations were made on all exposures of the Chattanooga formation. In places where the Chattanooga was not exposed, but where there were marked changes in the direction or degree of the dip of the accessible beds, strike and dip data were secured and the results used to supplement the determinations made on the Chattanooga. Numerous strike and dip readings and elevations were made on the Beaver Creek "sand," a readily identified bed of siliceous limestone in the New Providence shale. This "sand" served as an excellent substitute key bed, owing to the fact that its base is 40 to 45 feet above the top of the Chattanooga throughout the area.

SURFICIAL GEOLOGY

The Cumberland River, flowing through the area from east to west in a series of meanders, has cut a steep-walled valley through which the stream runs normally at about 590 feet above sea-level, while the general level of the upland is between 850 and 1000 feet above sea-level. The relief of the land in the north and the northwest part of the area is strikingly different from that to the southeast. In the north and northwest the relief is the result of the close dissection by streams which have carved steep-sided valleys and ravines leading back from the incised Cumberland. By contrast, in the southeast part of the area and in the region immediately beyond, the upland is generally flat, modified only by shallow sinks and a few hills that rise to a height of about 400 feet above its surface. This general character of the topography suggests former base-leveling and rejuvenation, so that now the Cumberland River is flowing some 300 feet below its old valley flat. In the southeastern part of the area the rocks of the upland are largely pure limestone; consequently, the water which falls there readily seeps below the surface, with the result that a system of underground drainage has been developed leaving the surface of the upland but slightly modified by erosion. On the other hand, in the north and northwest, the rocks are much more argillaceous and the water runs along the surface and down the short slopes toward the Cumberland, thus effecting the close dissection of the land.

STRATIGRAPHY

General Statement

The rocks of the area have a general dip to the southeast, owing to the fact that they are on the southeastern limb of the Cincinnati geanticline, the crest-line of which is several miles to the northwest of the area. As a result of the southeastward dip one encounters successively younger formations at the same level in going from the northwest to the southeast part of the area.

Most of the rocks of the area are of Mississippian age, but at some places along the Cumberland River and in a few of its tributary valleys older strata, Ordovician and Silurian, are exposed. To the south of the area Pennsylvanian strata are present at the surface. On the top of Big Hannah Hill, immediately south of the limits of the area and about two miles west of Mill Springs, the youngest Mississippian formations of the region are overlain by a thin covering of Pennsylvanian rocks. Southeastward from Big Hannah Hill the Pennsylvanian section thickens and progressively younger beds appear at the surface.

Description of Formations

Richmond limestone. — The oldest rocks of the area belong to the Richmond formation, which is included in the Ordovician system by some geologists and in the Silurian by others.

One of the best exposures of the Richmond is on the face of Shinbone Cliff a short distance below the mouth of Cub Creek. The lower part of the formation at this place consists of thin, even-bedded, greenish-gray limestones containing ripple marks and mud cracks. The upper half or more of the formation consists of uneven-bedded, greenish to brownish-gray, argillaceous limestones with a few thin intercalated layers of shale. The nodular appearance of the weathered surfaces of these beds readily distinguishes them from the even, ripple-marked beds below. A few of the argillaceous limestones contain fossils which are diagnostic of the Richmond.

According to Doctor Aug. F. Foerste,[1] the Richmond at the

[1] Foerste, Aug. F., "The Cincinnati Anticline in Southern Kentucky," *The American Geologist*, 30: 365. 1902.

mouth of Little Cub Creek, which is probably the same locality as that mentioned above, has a thickness of 19 feet. Measurements made by the writer indicate, however, that the thickness is about 46 feet. Excellent exposures of Richmond also occur along Forbush Creek, beginning at a point about one mile above its mouth and continuing for a distance of two miles upstream. The beds here are similar lithologically to those exposed on the face of Shinbone Cliff. At some places along the creek the upper 4 to 5 feet of the Richmond consists of even-bedded, greenish-gray limestones similar to those of the lower part of the formation.

Brassfield limestone. — The Richmond is overlain disconformably by the Brassfield limestone of lower Silurian age. This limestone is magnesian, somewhat arenaceous, thick-bedded and light brownish to reddish-gray. It is well exposed on the face of Shinbone Cliff about 300 feet south of Cub Creek. On the northeast limb of a small anticline at this place the greatest thickness shown is 9 feet 4 inches. Although the top of the limestone is not shown it is doubtful whether the total thickness is much greater.

Excellent exposures of the formation occur also along Forbush Creek and its tributaries. About half a mile above the mouth of Forbush Creek and just below the mouth of the first tributary entering the creek from the north, 15 feet of the limestone is shown, the basal part of the formation not being visible. The total thickness at this place is probably not greater than 17 feet.

Crab Orchard shale and limestone. — Overlying the Brassfield is a greenish-blue shale with intercalated thin layers of limestone which Dr. Aug. F. Foerste at first [2] assigned to the Osgood formation and later [3] placed in the Crab Orchard division of the Niagaran. The Crab Orchard, according to Dr. Foerste's classification,[4] includes the Indian Fields formation below and the Alger formation above. The Indian Fields formation contains

[2] *Op. cit.*, pp. 361–362.

[3] Foerste, Aug. F., "The Silurian, Devonian and Irvine Formations of East-Central Kentucky," *Kentucky Geol. Surv.*, Bull. 7, pp. 114–115. 1906.

[4] *Op. cit.*, p. 18.

two members, the Plum Creek clay below and the Oldham limestone above, and the Alger formation three members, the Lulbegrud clay at the base, the Waco limestone above and the Estill clay at the top.

Certain limestones in eastern Kentucky, which lie below the typical Plum Creek clay but still may be considered as a part of the Plum Creek clay member of the Indian Fields formation, contain *Whitfieldella subquadrata* Foerste. Frequently associated with this brachiopod are water-worn crinoid or cystid columnals and other fossils which, as stated by Dr. Foerste,[5] were originally included in the Brassfield limestone and subsequently incorporated in the basal beds of the Plum Creek clay.

According to Dr. Foerste,[6] 17 feet of Crab Orchard shale and limestone with remains of *Whitfieldella subquadrata* at the base rest upon $15\frac{1}{2}$ feet of Brassfield near the mouth of Little Cub Creek. In the valley of Forbush Creek near the house of William Richardson, which apparently is the house now occupied by Mr. W. L. Scott, this writer[7] reports a thickness of $1\frac{1}{2}$ feet of Crab Orchard.

The present writer did not observe as great a thickness of the Crab Orchard as did Dr. Foerste, owing to the fact that these exposures were either covered with talus or were not found by him.

The only exposures noted by the writer were located in the bed of Cub Creek about 200 feet north of the Russell-Wayne county line and in the bed of White Oak Creek about mid-way between the mouths of Laurel Fork and Lick Branch. At each locality only 18 inches of interbedded green shale and greenish-gray to buff limestone is exposed.

Chattanooga shale. — Unconformably overlying the Ordovician or Silurian formations is the Chattanooga shale of Mississippian age. This shale, the most easily recognized formation in the

[5] *Op. cit.*, pp. 36–38 and 44–45.

[6] Foerste, Aug. F., "The Cincinnati Anticline in Southern Kentucky," *The American Geologist*, 30: 362, 1902, and "The Silurian, Devonian and Irvine Formations of East-Central Kentucky," *Kentucky Geol. Surv.*, Bull. 7, pp. 114–115, 1906.

[7] As quoted in the first reference of note 6.

area, is thin-bedded and exceptionally well jointed (see Pl. XXXI). It is bituminous and contains scattered crystals of pyrite. Certain layers contain numerous remains of *Lingula* closely related to or identical with *Lingula melie* Hall. The formation is from 30 to 40 feet thick in most places where its entire thickness is exposed. The greatest thickness observed was 42 feet on the face of Shinbone Cliff.

A brown sandy formation quite commonly occurs at the base of the Chattanooga. In most places this sandy layer is only 1 or 2 inches thick, but in one locality, in a tributary that enters Forbush Creek about one-half mile above its mouth, the formation has a thickness of 3 feet.

New Providence shale. — The New Providence formation lies disconformably upon the Chattanooga shale and has a uniform thickness of from 80 to 100 feet throughout the area. It is characterized by having three distinct parts. The lower part consists of thin, uneven-bedded, greenish-gray shale about 40 feet in thickness. Above this is a massive, uneven-bedded and very hard siliceous limestone. It is pinkish-gray and contains irregular masses of chert (see Pl. XXXII, Fig. 1). This bed, the so-called Beaver Creek "sand," is about 5 to 10 feet thick and is important physiographically because of its tendency to form water-falls (see Pl. XXXII, Fig. 2). It has been given the name "sand" because it is an important oil-bearing formation in central and southern Wayne County. The upper part of the New Providence ranges in thickness from about 35 feet to 50 feet and is quite similar to the bottom part in its lithological characteristics.

Near the base of the New Providence phosphate nodules are common. Most of these nodules are about the size of hickory nuts but some, usually elongated, have a length of from 3 to 4 inches.

Fort Payne formation. — The Fort Payne formation seems to lie conformably on the New Providence. The measured thickness ranges from 100 feet to 124 feet. The lesser thickness was measured in the northwestern part of the area in a tributary to Cub Creek and the greater thickness on the bluff of White Oak Creek about one quarter of a mile below the mouth of Lick Branch.

On Shinbone Cliff and along the road north of the mouth of Forbush Creek the thickness of the Fort Payne is 115 feet.

The beds of the Fort Payne are primarily limestones which vary greatly in their lithological characters. Interbedded with the limestone beds are numerous thin, irregular layers of chert with occasional beds of shale. Thin, uneven-bedded, greenish-gray argillaceous limestones containing numerous quartz geodes are particularly characteristic of the formation.

Warsaw formation. — The Warsaw lies disconformably upon the Fort Payne. Its thickness ranges from about 40 feet, in the northeastern part of the area, to about 140 feet near the Bench Mark west of Shinbone Cliff. In the western part of the area, north of the Cumberland River and between Forbush and Cub creeks, there is a uniform thickness of between 100 and 110 feet, with a small amount of thickening southward. East of Forbush Creek there is a pronounced thinning toward the head of Lick Branch from all directions.

The Warsaw formation consists of limestones and shales of varied lithological character, some of the limestones grading horizontally into shale. Quartz geodes are common in some of the limestone beds. In many localities in the southwestern part of the area thick beds of bluish-gray shale make up a large part of the formation.

St. Louis limestone. — A disconformity separates the Warsaw from the St. Louis above. The St. Louis forms the surface of the upland south and east of White Oak Creek, increasing in thickness from a few feet along White Oak Creek to over 100 feet in the southeastern part of the area. North and east of White Oak Creek it occurs only near the tops of the highest elevations.

Massive beds of pure limestone are predominant in the St. Louis formation. Limestone sinks and red soils with numerous nodules and irregular masses of chert derived from the weathering of the limestone characterize the upland where the St. Louis is at the surface.

St. Genevieve limestone. — The St. Genevieve limestone overlies the St. Louis formation on the tops of Rankin Knob and the high elevation between Dry Branch and Cub Creek. The forma-

tion is composed of beds of oölitic limestone and is the youngest formation in the area. The St. Genevieve is 30 feet thick between Dry Branch and Cub Creek and about 100 feet thick on the top of Rankin Knob.

Formations south of the area. — South of the area studied younger beds of Mississippian age intervene between the St. Genevieve formation and the Pennsylvanian strata. These younger Mississippian rocks are the Gasper, Glen Dean and Pennington formations.

STRUCTURE

General Statement

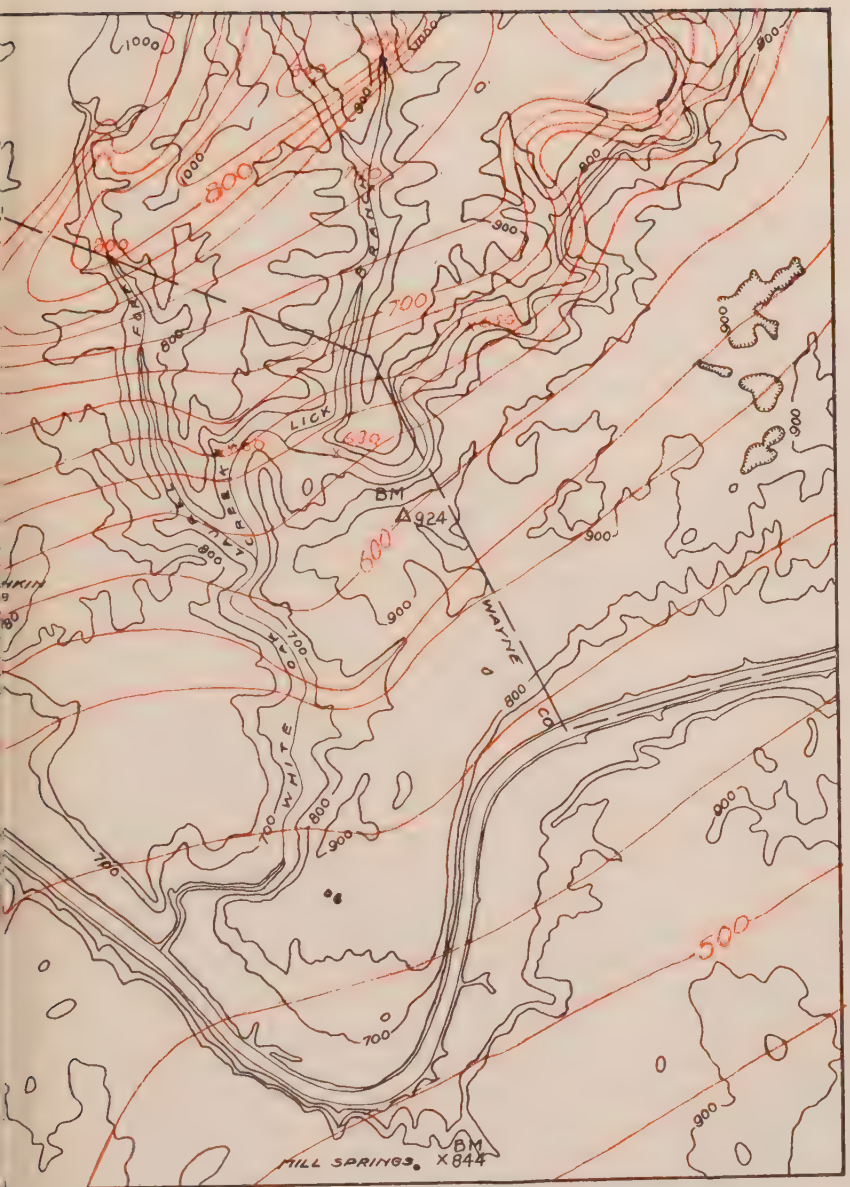
In general the strata of the region dip gently southeastward away from the axis of the Cincinnati geanticline. This average condition is markedly modified by a number of minor structures the general characteristics of which are defined by the undulations of the top of the Chattanooga shale (see structure map, Fig. 24).

In the northeastern part of the area there is a pronounced nose or dome, the summit of which is near the head of Lick Branch. Between this dome-like structure and Cub Creek, north of the Cumberland River and the lower course of Forbush Creek, the top of the Chattanooga shale presents the appearance of an unbroken plain sloping gently southward. There is an elongated dome south of the mouth of Forbush Creek, a second small dome west of Shinbone Cliff and a fault immediately to the west of the mouth of Cub Creek.

Local Features

The most prominent structural feature in the area is the dome in the northeastern part. The surface of this dome is modified by terraces and noses. The average dip of the top of the Chattanooga shale, measured down the southeastern slope of the dome from near the head of Lick Branch to White Oak Creek, is 150 feet to the mile (about 1° 38′). Locally, in several places, the dip of the strata is more than 6 degrees in the direction of the general slope of the structure and in Lick Branch the Chattanooga shale

FIG. 24. STRUCTURAL MAP OF PARTS OF WA
SHOWING, IN RED, CONTOURS ON



MILES
2

×640 ELEVATION IN FEET ABOVE SEA LEVEL ON TOP OF CHATTANOOGA SHALE
FAULT
GAS WELL
INCOMPLETED WELL

ULASKI AND RUSSELL COUNTIES, KENTUCKY,
P OF THE CHATTANOOGA SHALE

has such a dip of about 20 degrees. Immediately above slopes of this nature the beds are virtually horizontal and in some places seem to have a slight dip in the opposite direction. These local accentuations of the slopes of the structure disclose the terraces and noses that vary its surface.

The most conspicuous nose on the structure is in the northeastern part of the area at the juncture of the two forks of White Oak Creek. On the front or east slope of the nose there is a dip of 15 degrees. This dip was observed along the road on the west side of the creek. About one quarter of a mile west of the creek and at an elevation of 120 feet above the creek the strata are nearly horizontal. On the north side of the nose there is a dip of 7 degrees northwest.

The west slope of the dome is suggested by the elevations of outcrops of Chattanooga shale and Beaver Creek "sand" in Laurel Fork and by dip determinations on beds of the Fort Payne along the tributary from the northeast, which joins Laurel Fork near its head. Along this tributary there is an average westward dip of nearly 2 degrees. At the mouth of the tributary the dip of the Fort Payne beds is 11 degrees west and about 300 feet upstream the dip is 7 degrees east, indicating the presence of a nose on this slope of the dome.

Another prominent structure of the area is a low, elongated dome, the top of which is south of the Cumberland River opposite the mouth of Forbush Creek. The outlines of this dome are well established by the elevations of the top of the Chattanooga shale exposed at several places on the structure. The highest observed exposure of the Chattanooga shale is on the south side of the Cumberland valley opposite the mouth of Forbush Creek, the elevation of the top of the shale at this point being 676 feet.

A third dome is present immediately west of Shinbone Cliff. The highest point noted on the structure was observed in the more southern of the two ravines entering the valley back of the north end of Shinbone Cliff from the west. The elevation of the top of the Chattanooga shale in this ravine is 685 feet.

A normal fault occurs across the nose of Shinbone Cliff a short distance below the mouth of Cub Creek. The strata displaced

belong to the Richmond, Brassfield and Chattanooga formations. The strike of the fault plane is north 22 degrees west and the dip is 89 degrees northeast. The vertical displacement of the bottom of the Brassfield is 15 feet 6 inches. On the northeast or downthrow side of the fault the bottom of the Brassfield is about 28 feet above the low water level of the river. The strike of the Brassfield on this side of the fault is north 60 degrees west and the dip is 22 degrees northeast. Northeastward from the fault the angle of dip lessens perceptibly and near the mouth of Cub Creek, where the Brassfield is at the level of the river, it is only 9 degrees, indicating that the displacement along the fault plane was accompanied by considerable drag on the downthrow side. On the southwest side of the fault the bottom of Brassfield is about 43 feet above the river. At this place the thickness of the Brassfield is 8 feet 10 inches, with a covered interval of 10 feet between the top of the formation and the Chattanooga shale.

On the south facing slope of the valley back of Shinbone Cliff there is an exposure of the Chattanooga in which the beds have a steep dip to the northeast as they have on the face of Shinbone Cliff northeast of the fault. Apparently the fault does not extend more than a short distance beyond this point, because the beds of the Chattanooga shale, where exposed along the creeks a short distance farther north and northwest, are nearly flat and show no indication of faulting. South of the Cumberland River no evidence of the fault could be found.

Rocks younger than the Chattanooga shale are not exposed at any place where the fault was observed; hence, the time of the faulting cannot be determined.

College of the City of Detroit
Detroit, Michigan

PLATES XXXI–XXXII

PLATE XXXI

FIG. 1

FIG. 2

PLATE XXXII

FIG. 1

FIG. 2

EXPLANATIONS OF PLATES

PLATE XXXI

FIG. 1. Typical exposure of Chattanooga shale, showing laminated character of the formation. View taken along tributary stream of Forbush Creek

FIG. 2. Jointing in Chattanooga shale. View taken along tributary of Coldweather Creek near juncture of Coldweather and Fishing creeks about seven miles northwest of Somerset, Kentucky

PLATE XXXII

FIG. 1. Weathered surface of Beaver Creek "sand" member of New Providence shale, showing characteristic irregular masses of chert of this member. View taken on slope above house of Mr. W. L. Scott near mouth of Forbush Creek

FIG. 2. Lower part of New Providence shale and capping bed of Beaver Creek "sand." View taken in tributary of Laurel Fork about one and one-quarter miles north of White Oak Creek

STRATIGRAPHY OF CHIPPEWA COUNTY, MICHIGAN

WALTER A. VER WIEBE

THE data presented in the following pages are based upon material collected and work done during the summer of 1926. The field-work was conducted as part of an inventory of the natural resources of Chippewa County made by the Land Economic Survey of Michigan.

LAKE SUPERIOR SANDSTONE

The oldest Paleozoic formation exposed in Chippewa County is a sandstone of variable thickness and character. At one time it was the subject of a great controversy in which European as well as American geologists were involved. Even now the age of this formation is not satisfactorily defined. Fossils from the Lake Superior sandstone were reported by a number of geologists, but none of these were found *in situ*. The writer feels, therefore, that he was particularly fortunate in 1926 when he came upon some fossils in the Lake Superior sandstone at Sault Point. They were sent to Dr. Ulrich for identification. He states that they belong to the genus *Ophileta* and that probably three species are represented. In his opinion the rocks are of Canadian or Ozarkian age. In this connection see Rominger [1] regarding *Ophileta levata* in conglomeratic limestone blocks.

Outcrops in Chippewa County. — In Chippewa County outcrops of the Lake Superior sandstone are not numerous. The most extensive outcrops appear in the Taquamenon River, about fourteen miles above its mouth. The rock is a nearly pure, siliceous sandstone in thin beds, and with considerable cross-bedding. About fifty feet of rock is exposed in the rapids. In the upper falls of the Taquamenon another sixty or seventy feet of

[1] Rominger, Carl, *Geol. Surv. Mich.*, 1, 1869–73, p. 74.

sandstone appears. This section is more variable than in the lower falls, showing some soft sandstone, some coarse layers, some shaly layers, and some deep red shale layers.

Another outcrop of considerable extent is the one in the rapids of the St. Mary's River at Sault Ste. Marie. The most interesting outcrop in the county, however, appears along the shore-line of Lake Superior at Sault Point. The outcrop begins near the northeast corner of Section 30, T. 47 N., R. 4 W., and extends almost to the north line of Section 19. There is a total thickness of about fifteen feet exposed in this distance. At the base the sandstone is soft, greenish, shaly and thin-bedded. One foot above the base *Ophileta* occur in considerable numbers in a soft, friable, sandy matrix. Above this level the sandstone is harder, but irregularly bedded. The best way to reach this locality is to set out from the Dollar Settlement. A passable sand road leads along the shore to Pendell's Creek. From there a trail runs north to the lake, whence easy travelling will take one to the outcrop.

The thickness of the sandstone varies greatly, because it fills the depressions in a late Algonkian land surface, which appears to have been quite rugged. In the well drilled by A. W. Palmer for the American Alkali Co. near Sailors' Encampment Island, T. 45 N., R. 2 E. (Section 36 ?), the sandstone is 194 feet thick. The upper 161 feet is white and the lower 33 feet red. In the Pickford well the thickness is uncertain; it may be 800 feet, but is probably less.

ORDOVICIAN ROCKS

The rocks which can be assigned to the Ordovician system were found and described at an early date. In Jackson's report of 1847 [2] Locke describes the outcrops in the St. Mary's River at the lower Neebish rapids. Robert Bell states on page 111 of his report for 1869 [3] that "the Trenton strikes and enters

[2] Jackson, Chas. T., U. S. 30th Cong., 1st Sess., Sen. Ex. Doc. 2, pp. 175–230. 1847.

[3] Bell, Robert, *Report on the Geology of Manitoulin, Cockburn, Drummond and St. Joseph's Islands;* Geol. Surv. Can., Rept. Prog., 1866–69, pp. 109–116. 1870.

Michigan at Neebish Island"; and, on page 113, that "on the north side of Drummond Island the upper beds of the system are exposed which as usual are of a massive calcareous nature and form a strip about seven miles long and two broad." Rominger in his report of 1873 [4] describes the outcrops quite completely on pages 54–79.

Black River (?) of Chippewa County. — The author of this paper is inclined to believe that the formations of the lower part of the Ordovician will be found to differ somewhat from west to east across the Upper Peninsula. He has studied the formations in Menominee County as well as in Chippewa County and believes that the typical part of the Calciferous of Rominger, called Hermansville in Menominee County, is missing farther east. Few fossils are to be found in the Hermansville, but its lithologic character is very distinctive. It is a coarse, sugary, friable, porous dolomite, with greenish cavity filling at many places. Such a rock is not to be found in Chippewa County. Not only are there no outcrops of such a rock, but also no trace of such a rock is to be found in the rather numerous drift boulders.

Instead of the Hermansville, a different kind of rock appears below the Trenton. It is a fairly hard dolomite, of dark grey color, which breaks into large rectangular pieces and which can readily be distinguished from the typical Trenton. E. O. Ulrich and G. M. Ehlers have examined this rock and its contained fauna at the upper end of the Neebish channel cut and consider it to be the probable equivalent of the Black River.

Waiska River outcrop. — The most remarkable outcrop of Black River is in the Waiska River southwest of the village of Brimley in the northwest quarter of Section 29, T 46 N., R. 2 W. The river runs over rapids which begin close to the section-line between sections 29 and 30 and extend toward the east for about half a mile. Toward the eastern end of the rapids the solid ledges of limestone may be seen, but farther west they are obscured by alluvial material and fallen blocks. The two or three feet exposed may be described as very massive and hard lime-

[4] Rominger, Carl, *Geol. Surv. Mich.*, 1, 1869–73.

stone. It resembles the lower part of Rominger's Trenton, as revealed in the Menominee River, more closely than any rock seen in the Upper Peninsula. Some fossils are present. The river has cut down through the Algonquin lake clay nearly 50 feet along the rapids. At one point the river has bared an ancient wave-cut cliff. In this cliff additional layers of the Black River may be seen, but in a peculiarly jumbled condition. The cliff looks as though it had been undercut by waves and large blocks of the overhanging portion had tumbled down. In the upper part of the cliff the typical Trenton limestone crops out.

Neebish Island outcrops. — The same kind of rock crops out on both sides of Neebish Island. Along the western side a narrow channel has been blasted out for the ships that pass down the St. Mary's River. Great piles of rock 30 to 40 feet high line both sides of the channel for a distance of over one quarter of a mile in Sections 20, 28 and 29 of T. 45 N., R. 2 E. This is hard, dark, massive and coarsely crystalline limestone. Walls have been built in the channel with blocks of the same limestone, which break up into large rectangular blocks ideal for such a structure. In the rock of the wall the most common fossil is a large *Orthoceras*, five to six inches in diameter and four feet long; other fossils are not at all numerous. In certain places of the wall some black, shaly limestone blocks are common. These are usually well filled with a large variety of invertebrates. On the other side of Neebish Island, there is another outcrop of the same rock. It forms the floor of a small stream channel which separated Neebish Island from Sailors' Encampment Island in times of higher water. The outcrops are in Sections 36, T. 45 N., R. 2 E., and 31, T. 45 N., R. 3 E. Only the flat surface of a hard, buff crystalline limestone is to be seen at present. Farther east there are some low cliffs which probably are rock cliffs with a very thin cover of glacial material. Numerous blocks of Trenton lying about indicate that this is not far from the stratigraphic boundary between the Black River and the Trenton. A well drilled near this outcrop is recorded by Lane in the state geologist's report for 1901. The record of this well is also given by

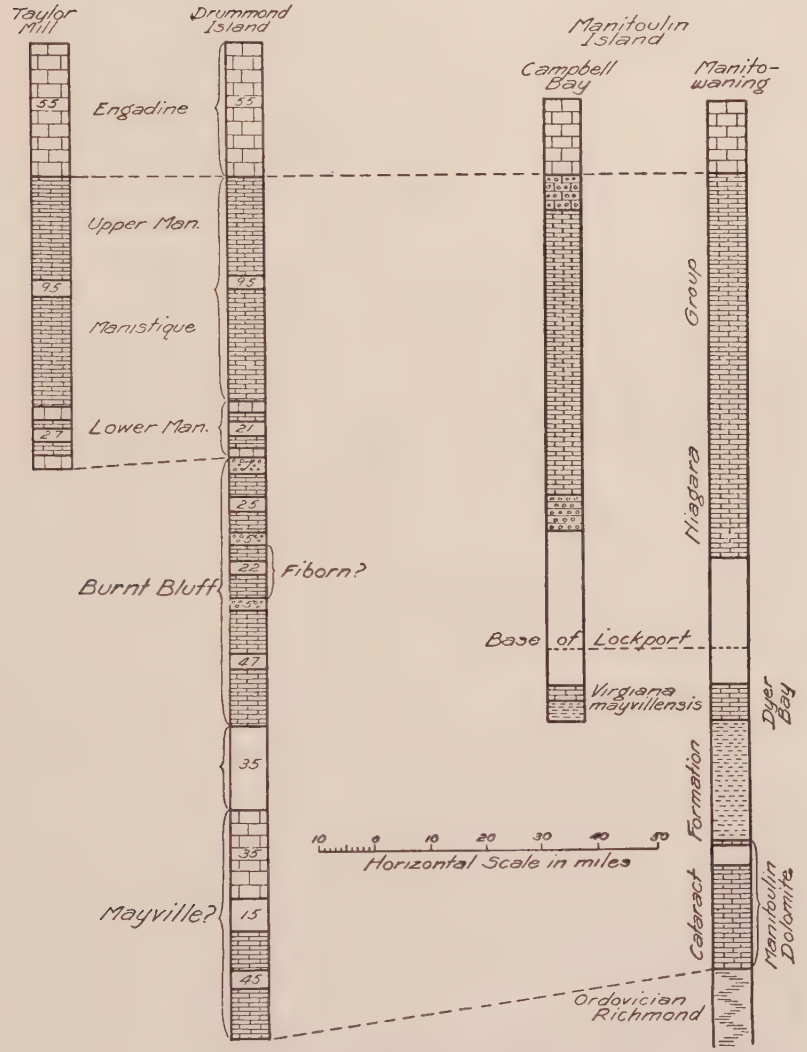


FIG. 25. Stratigraphic sections to illustrate Silurian rocks in Chippewa County and to show correspondence with the Silurian of Ontario

Smith,[5] but in his report the details are quite different from those given by Lane. Smith gives the Trenton a thickness of 190 feet with 161 feet of St. Peter sandstone. More than likely what is here called the St. Peter is the upper or white portion of the Lake Superior sandstone.

Pickford well. — In 1906–7 a deep well was drilled at Pickford for oil. Dr. Lane compiled the record from a partial set of samples and this record is published by Smith.[6] Lane shows 132 feet of surface deposits down to the Niagara (Lockport) limestone. To this he gives a thickness of 128 feet, then to the Lorraine 215 feet, and to the Utica 50 feet, down to the Trenton. These correlations are subject to revision in the light of the author's studies in Chippewa County. The author found the *Pentamerus oblongus* zone (base of Manistique) at an elevation of 730 feet above sea-level in the hilly region four miles south of Pickford (see Taylor Mill section in Fig. 25). The elevation at Pickford is 605 feet above sea-level. Allowing 132 feet in depth for the distance down to solid rock gives 473 feet for the top of the so-called Niagara. Assuming a dip to the south of 40 feet to the mile, or 160 feet, would give the Pentamerus layer a height of 890 feet above Pickford. Now, according to a carefully measured section which the author made for Drummond Island (see Fig. 26) the interval between the lower Pentamerus layer and the top of the Ordivician is equal to not less than 240 feet and probably not more than 290 feet. Subtracting 290 feet from 890 feet would place the top of the Richmond at 600 feet, or about at the surface of the ground at Pickford. At a depth of 132 feet, therefore, we should be well within the Richmond after allowing liberally for a thickening of the formation from Drummond toward the west. The 128 feet given as the thickness for the Niagara must, therefore, belong to the Richmond or at least to the Cincinnatian. The revised section would then read as follows:

[5] Smith, R. A., "The Occurrence of Oil and Gas in Michigan," *Mich. Geol. and Biol. Surv.*, Publ. 14, 1912, p. 244.

[6] *Ibid.*, p. 245.

	Thickness in feet	Depth in feet
Clay	119	119
Sand	13	132
Richmond	128	260
Lorraine (?)	215	475
Utica (incl. Collingwood)	50	525
Trenton and Black River	275	800

Glacial boulders. — A careful examination of the boulders on the marginal moraines of Chippewa County adds considerable to our knowledge of the areal distribution of the Black River. Localities where such boulders were seen are indicated on the map, Figure 27.

Trenton limestone. — The Trenton limestone is exposed at only one locality in Chippewa County. This is the outcrop described in the foregoing pages as occurring in the Waiska River, southwest of Brimley. At this locality the upper part of the ancient sea cliff uncovered by the Waiska River shows some layers of a very white limestone, which has lumps of clay scattered through it that produce greenish spots. It is a very even and thin-bedded limestone and contains many fossils. This limestone is exactly like the Trenton so well shown one-half mile north of the town of Bark River in Delta County (Galena Limestone of Wisconsin ?). G. M. Ehlers reports finding Trenton fossils in rock from the southern end of Neebish channel cut.

Glacial boulders. — In Chippewa County boulders of this (Trenton) rock are found at widely scattered points in the glacial drift. The pieces are so distinctive that they may be recognized without difficulty. Those which are weathered are still very white and show a strong tendency to split into thin sheets because of the greater solution along parting planes. The pieces are tabular with jagged edges. The muddy spots are prominent and fossils are common. Localities where these were seen are shown on the map, Figure 27.

When paleontological studies have been completed on the faunas contained in these Ordovician strata, it will probably be found that they represent the Lowville, Black River and Trenton of the New York section. The most recent discussion of Ordovician rocks in neighboring areas is to be found in Guide Book No.

5 (*Excursion in the Western Peninsula of Ontario and Manitoulin Island* [7]), where August Foerste describes the Mohawkian (middle Ordovician) on Manitoulin Island and the small islands between it and the mainland. He differentiates the following members:

Trenton limestone	
Black River	80 feet +: dark limestone
Lowville (Leray)	soft white limestone with 11 feet of fine-grained hard limestone at top
Lowville (lower)	70 feet +: red shales

Cincinnatian. — The uppermost portion of the Ordovician is the Richmond formation. In other areas, notably in New York and Canada, the Richmond is separated from the Trenton by the black Utica shale and the blue Lorraine shale. These may be present also in Chippewa County. A piece of black shale was found on Drummond Island in Section 6, T. 42 N., R. 7 E. It is difficult to see how this bituminous shale should appear in this strip unless the black shale is present farther north. Some pieces were also seen in a gravel pit in the southeast quarter of Section 10, T. 44 N., R. 1 W. Bell mentions finding fragments of Utica shale on St. Joseph's Island. On Manitoulin Island, east of Chippewa County some sixty miles, he reports an outcrop at Maple Point. In the Pickford well 50 feet of black shale is reported and 215 feet of Lorraine shale.

In Chippewa County the Richmond crops out only along the north shore of Drummond Island, where it appears at frequent intervals over a stretch of seven miles. In this stretch there are cliffs 20 or more feet high and the outcrops continue below water level for an equal thickness. These outcrops were described by Bell [8] under the name of Hudson River. Later, Rominger [9] described them more fully and listed the fossils. The rocks exposed along the north shore of Drummond Island may be described as shaly limestones or argillaceous limestones. The color is dark grey and they are not very hard. Fossils are rather plentiful.

In the Pickford well, discussed in the preceding pages, the

[7] Geol. Surv. Can., Int. Geol. Congr., 1913.
[8] Page 111 of work cited in note 3.
[9] Rominger, Carl, *Geol. Surv. Mich.*, 1, 1869–73.

Richmond (?) appears to be at least 128 feet thick. The blue shale (Lorraine ?) below it is 215 feet thick and the Utica black shale is given a thickness of 50 feet.

Correlation of the Cincinnatian. — The Utica can be traced from New York into Ontario chiefly by its characteristic lithology. Black shales are to be found in a strip running north through Ontario to Bruce Peninsula and thence to Manitoulin Island. These may be the equivalent of the Utica or of only a portion of it. Raymond applied the name Collingwood to these and Foerste used the same name in describing the outcrops on Manitoulin Island. In Michigan Ruedemann and Ehlers [10] have found the Collingwood fauna in drift specimens a short distance west of Chippewa County. It appears probable, therefore, that a portion or the whole of the 50 feet of black shale in the Pickford well is to be considered as Collingwood in age.

The Lorraine can be traced from New York to Manitoulin Island, though it is likely that the name Lorraine will be supplanted by local names or perhaps by names taken from the Cincinnati area. Foerste says, after discussing the Lorraine of Ontario and Quebec: [11] "From the preceding observations it becomes evident that the richly fossiliferous Waynesville horizons . . . are underlain by horizons lithologically resembling the Pulaski part of the Lorraine, and containing in the upper parts at least the lamellibranch *Pholadomorpha pholadiformis*. . . . It is doubtful whether the use of the term Lorraine . . . can be of great value. . . . The use of the terms Maysville and Eden for the strata exposed in Ontario may eventually prove much more appropriate." The Eden on Manitoulin Island consists of clays, greenish and soft above and more fissile below, with a thickness of 107 feet near Little Current. The Maysville in the same region consists of clay shale with occasional limestones having a thickness of 114 feet at McLean Hill south of Little Current.[12]

The Richmond formation is also present on Manitoulin Is-

[10] Ruedemann, R., and Ehlers, G. M., "Occurrence of the Collingwood Formation in Michigan," *Contrib. Mus. Geol., U. of M.*, 2: 13–18. 1924.

[11] Foerste, Aug., "Upper Ordovician Formations of Ontario and Quebec," *C. G. S.*, Memoir 83, p. 95. 1916. See also pp. 27–28.

[12] Foerste, Aug., *op. cit.*, p. 91.

land. In a section northwest of Kagawong, Foerste measured 127 feet of this formation most of which is solid limestone, the rest being argillaceous limestone.[13] If we total the thicknesses found by Foerste [14] on Manitoulin Island we can construct the following table:

Richmond	127	
Maysville	114 to 170	
Eden	107	(excluding Collingwood)
Collingwood	22?	
Total	365 to 421	

In the Pickford well a total of 393 feet of Cincinnatian rocks was encountered. As stated on page 314, however, the top of the Richmond is probably missing for about 130 feet. It is very likely, therefore, that the Cincinnatian has thickened toward the west in the 60 miles from Manitoulin Island, so as to have a thickness of roughly 520 feet.

SILURIAN ROCKS

The Silurian rocks of Chippewa County are very interesting, partly because they are better developed on the outcrop and partly because they have been more extensively described than the other rocks. The oldest strata which appear to belong to this system were found on Drummond Island in the Potagannissing area. The upper 20 feet or so of these strata is a massive bryozoan or coral reef. The best place to study it is in the center of Section 9, T. 42 N., R. 6 E., where the waters of the bay have washed it clean and brought it into prominence. It may be described as a very hard limestone which is porous and extremely massive. Some of it is blue and some buff. Scattered through the mass are small siliceous pipes or stems of bryozoan or coral fragments. The only complete specimen seen by the writer is a species of *Favosites*. This ancient reef can be traced over a considerable area as it produces low, rocky mounds devoid of vegetation. One such mound may be seen in the exact center of Section 10, where the road passes over it. Another may be found

[13] *Ibid.*, p. 105.

[14] Guide Book No. 5, p. 89, Geol. Surv. Can., Int. Geol. Congr., 1913.

on the farm of Mr. Stevenson near by. Fossils collected from this stratum by G. M. Ehlers indicate that it is probably equivalent to the lower part of the Mayville.

Below this reef rock there appears to be a thin-covered interval of possibly 15 feet. In the succeeding part of the section dolomites appear which resemble those of certain portions of the Niagara. They are probably 40 to 45 feet thick, but only the upper and lower strata are exposed. The lowest strata were seen by the writer on the south side of a marsh located in the north part of Section 3, T. 42 N., R. 6 E. Here 12 feet of dolomite crops out in a bluff which extends some distance east and west of the end of the road or trail from the south. The rock is greyish-blue on a fresh exposure, but weathers very quickly to a dull yellow. It is medium-grained in texture and breaks into fairly regular pieces roughly 8 inches thick and rectangular. It is marred by small nodules of chert which also seem to decay rapidly on exposure to weathering. The upper layers of the 40-foot interval crop out at lake level on Walter Stevenson's farm in the southwest quarter of Section 3, T. 42 N., R. 6 E. This is a very hard dolomite which weathers deeply, however, with a brown concentric shell. Some fossil fragments were observed here.

In the absence of paleontologic evidence, these strata are difficult to place. They may be of Mayville age or possibly even of Richmond age though the writer believes this is unlikely. The writer searched for a rock of similar stratigraphic position and lithology. The Manitoulin dolomite described by M. Y. Williams appears to come as close as anything he was able to find. This dolomite has a thickness of 50 feet near Manitowaning (on Manitoulin Island) and also has local coral and bryozoan reefs in the upper 20 feet.[15]

Niagaran rocks. — Above the dolomites just described there is a covered interval which includes possibly 35 feet of strata. This is succeeded by dolomites of Niagaran age with an aggregate thickness of approximately 285 feet. In describing these strata in detail the writer will use the nomenclature suggested by Eh-

[15] Williams, M. Y., *The Silurian Geology and Faunas of Ontario Peninsula and Manitoulin Island*, Can. Geol. Surv., Memoir 111, 1919, p. 28.

lers,[16] since he feels that the paleontological evidence brought together by Ehlers and now in manuscript form nearly ready for the press will establish the validity of the classification.

Mayville formation. — Ehlers defines the Mayville as the "northeastward continuation of the Mayville of Wisconsin. The base of the formation in Michigan has not been seen; the top is provisionally placed at the top of a yellowish grey dolomite containing numerous remains of the brachiopod named *Virgiana mayvillensis* by Savage."

In Chippewa County there are no outcrops of the Mayville to be seen on the mainland, but on the islands, notably Lime Island and Drummond Island, the beds are known to occur. The writer has not been on Lime Island, but the top layer of the formation containing the Virgiana has been found there by Ehlers. On Drummond Island Ehlers reports finding the same fossil as far north as Section 15, T. 42. N., R. 7 E., along the eastern side of the island in wave-drifted boulders.

Burnt Bluff formation. — The Burnt Bluff formation is described by Ehlers as the "northeastward extension of the Byron, Transition and lower part of the Lower Coral Beds of Wisconsin." This formation crops out at a number of places on the mainland of Chippewa County, but is particularly well displayed on Drummond Island. One of the best places to study it is in the L. Seamon quarry at the western edge of the village of Drummond. In this quarry the top layer is very distinctive because it weathers out with a peculiar nodular or gnarled surface on account of differential weathering. It is coarse-grained and deeply iron stained to buff, cream, or brown. Inasmuch as this layer proved to be an excellent key horizon, the writer named it the *lower nodular layer* and it will be so referred to in the following pages where it is necessary to clarify the stratigraphic position of layers in a section. It was called the lower nodular layer because two others were found in the Burnt Bluff, just like it in every respect, which were named the *upper* and *middle nodular layers*. Below the lower nodular layer in the

[16] Ehlers, G. M., "The Niagaran Rocks of the Northern Peninsula of Michigan" (Abstract, *Bull. G. S. A.*, 32: 129. 1921.)

Seaman quarry there is a somewhat monotonous succession of strata which may be described in general as very hard, even-bedded, light grey to pale buff, fine-grained dolomite. A striking characteristic is the presence of thin, dark to black, carbonaceous bands, parallel to the bedding which give the rock the appearance of "ribbon structure" when freshly fractured. Another striking feature is the fact that the jointing is so well developed in two sets of joints at right angles producing rectangular blocks.

Lime kiln quarry. — These same characters distinguish the rock in the lime kiln quarry which is located in Section 18, T. 42 N., R. 6 E., near the shore-line of Potagannissing Bay, where the following section was measured.

SECTION IN LIME KILN QUARRY, DRUMMOND ISLAND

(Elevation at top, 653 feet above sea-level)

	Thickness in feet	Total in feet
1. Middle nodular layer, coarse, cream-colored, porous, weathers with nodular surface	1	1
2. Interval mostly covered, but typical, broad-banded limestone of Fiborn (?) may be seen	22	23
3. Lower nodular layer, like No. 1	2	25
4. Covered	4	29
Top of quarry		
5. Dolomite, thin-bedded, even-bedded, grey, fine-grained	3	31
6. Dolomite, brownish, medium-grained	4	35
7. Dolomite, yellow, medium-grained	5	40
8. Dolomite, light cream color, saccharoidal	2	42
9. Dolomite, brownish, moderately coarse, friable	5	47
10. Dolomite, thin and even-bedded, rectangular jointing, thin bituminous partings, partly covered to lake	25	72

Other outcrops. — On the point one-half mile west of Drummond village, the Burnt Bluff forms the shore-line for some distance and fossils are present. Again, on the point one and one-half miles east of the village (Sections 17 and 18, T. 42 N., R. 6 E.), the lower part of the formation may be studied. In the narrow strip shown on the areal geology map it crops out at many places, the most convenient one being along the road to

Maxton especially in the northeast corner of Section 21, T. 42 N., R. 6 E.

Fiborn. — On Drummond Island the Niagara may be studied in its entirety, from the top of the Engadine down to near the base of the Burnt Bluff (see Fig. 26). In the thickness of 285

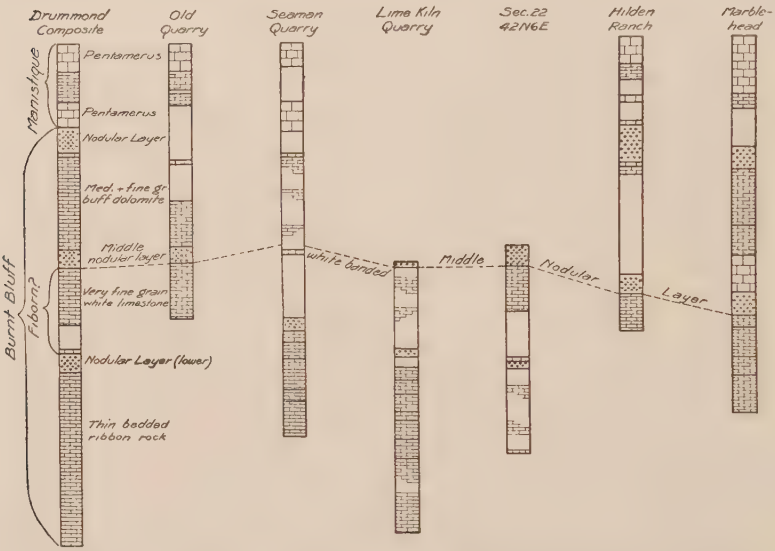


Fig. 26. Stratigraphic sections across Drummond Island to illustrate character of middle Silurian and persistence of Fiborn

feet there are no beds which exactly resemble the Fiborn limestone. The beds which most nearly approach the Fiborn as described by Smith are a zone of 22 feet, lying 37 feet below the top of the Burnt Bluff formation. The best place to see it is in the old quarry one mile west of Drummond village. Here the following section was made by the writer. The uppermost five feet are most typical, and layer No. 11 stands out because of its striking white color, and because it weathers out in broad ribbon bands one to three inches wide. The writer did not see any other layer just like this one in the whole 285 feet of the Niagara exposed on Drummond Island.

SECTION IN OLD QUARRY ONE MILE WEST OF DRUMMOND VILLAGE

(Elevation at base of quarry, 615 feet above sea-level)

Manistique formation

	Thickness in feet	Total in feet
1. Upper Pentamerus layer, massive dolomite, cream-colored, coarsely crystalline, filled with casts of *Pentamerus oblongus*, weathers dark brown	7	7
2. Dolomite, thin-bedded, weathers into white sheets	5	12
3. Dolomite, one layer, very hard, medium-grained, buff	¾	12¾
4. Dolomite, thin-bedded, pale grey, very fine grained	3	15¾
5. Covered	15	30¾
Burnt Bluff		
6. Dolomite, one layer, saccharoidal, brownish	1	31¾
7. Covered	10	41¾
8. Dolomite, thin-bedded and even-bedded, buff and grey, medium-grained and lithographic	11	52¾
Top of quarry		
9. Middle nodular layer, coarse, cream-colored dolomite	4½	57¼
Top of Fiborn (?) member		
10. Limestone, fine-grained, buff	2¾	60
11. Limestone, lithographic, weathers white, broad bands	3	63
12. Dolomite, medium-grained, buff	2¼	65¼
13. Limestone, lithographic, grey	½	65¾
14. Dolomite, like No. 12	½	66¼
15. Limestone, like No. 13	2¼	68½
16. Limestone, pale yellow	1¼	69¾
17. Limestone, like No. 13	¾	70½
18. Dolomite, medium-grained, buff, hard	1¾	72½

The white broad-banded rock (No. 11) can be traced from this quarry to the L. Seaman quarry one mile east. It appears again in a high cliff in the northern part of Section 22, T. 42 N., R. 6 E. From this point it can be followed for a distance of over a mile into Section 23. In this stretch the middle nodular layer is the cliff-forming rock and has protected the Fiborn (?)

from erosion. Behind it, to the south, other rock terraces appear held up by higher members of the section. By means of these related rocks the Fiborn (?) can be traced to Marblehead in Section 31, T. 42 N., R. 8 E., at the eastern extremity of the island.

Marblehead. — The stratigraphic sequence at Marblehead was carefully measured by Rominger, whose section is reproduced by Smith.[17] Smith suggests that layer No. 10 is the probable equivalent of the Fiborn and cites a chemical analysis (No. 237 of the same publication) to corroborate this conclusion. This analysis shows 95 per cent of calcium carbonate. On this basis it does not seem unreasonable to include Nos. 11 and 12 of Rominger's section, inasmuch as No. 12 shows 94 per cent of calcium carbonate. These three beds together total a thickness of 16 feet. Bed No. 9 in Rominger's section is probably the middle nodular layer, so characteristically present above the Fiborn (?) farther west.

Ehlers has found in several places west of Chippewa County evidence that seems to indicate that the Fiborn and some lower beds grade laterally into dolomite. Further he is inclined to believe that the beds which are the equivalent of the Fiborn on Drummond Island are dolomites and occur higher up in the Burnt Bluff formation than these selected by the present writer.

Manistique. — The second division of the Niagara, Ehlers calls the Manistique, using the name first suggested by Smith *but in a more restricted sense.* He defines the Manistique as the "northeastward extension of the Upper Coral Beds and the upper part of the Lower Coral Beds of Wisconsin." The writer has arbitrarily subdivided this formation into an upper and a lower division which will be called in this paper simply *upper Manistique* and *lower Manistique.* This distinction is desirable on account of the lithologic differences which set off the divisions. The upper division consists of 95 feet of thin-bedded cherty, fossiliferous dolomites. The lower division consists of two beds of massive brownish coarse dolomite with numerous casts of

[17] *Limestone of Michigan,* Mich. Geol. and Biol. Surv., Publ. 21, 1915, p. 207.

Pentamerus oblongus with some interbedded thin dolomites. It was found convenient in the field to distinguish the two *Pentamerus* layers as the upper and the lower *P. oblongus*. They are so used in this paper without implying that they are regarded as formation names or member names.

The most convenient place to study the lower Manistique is on the Victor Hilden ranch, in the northwest quarter of Section 26, T. 42 N., R. 6 E., the details of which are given below.

SECTION ON VICTOR HILDEN RANCH

(Elevation at top of section, 695 feet above sea-level)

Lower Manistique	Thickness in feet	Total in feet
1. Upper Pentamerus layer, massive, light cream colored, coarsely crystalline, casts of *P. oblongus*, weathers dark chocolate-brown	7	7
2. Dolomite, weathers into thin white sheets	4	11
3. Covered	4	15
4. Lower Pentamerus layer, like No. 1	2	17
5. Covered	5	22
Burnt Bluff		
6. Dolomite, one layer, saccharoidal, brownish, weathers rounded edges	1	23
7. Upper nodular layer, coarse, sugary dolomite, weathers dark	10	33
8. Same as No. 6	1	34
9. Dolomite, thin, hard, buff, medium- to fine-grained	2	36
10. Covered. Section continues one eighth of a mile to north	27	63
11. Middle nodular layer, coarse, cream-colored, porous	5	68
Fiborn (?) member		
12. Thin and even-bedded limestone, some buff and hard, others grey. The typical white, broad-banded rock is prominent	10	78

In this section the upper Pentamerus layer shows up in its full thickness. Only 4 feet of the thin-bedded white dolomite between the two Pentamerus layers is revealed here. These layers are seldom seen in their entirety. The only place where they crop out in full thickness is above the old quarry in Section 23, T. 42 N., R. 5 E. The lower Pentamerus layer is also visible

only in part. The best place to study this layer is in the hillside behind the L. Seaman quarry.

SECTION IN L. SEAMAN QUARRY AT DRUMMOND VILLAGE

	Thickness in feet	Total in feet
Lower Manistique		
1. Upper Pentamerus layer	6	6
2. Covered	11	17
3. Lower Pentamerus layer, coarse, porous, brown dolomite crowded with casts of *P. oblongus*, like No. 1	8	25
Burnt Bluff		
4. Covered	6	31
5. Dolomite, one layer, saccharoidal, brownish, weathers with rounded edges	1	32
6. Dolomite, thin and even beds, buff and grey, largely covered	25	57
Fiborn (?) member		
7. Limestone, lithographic, weathers white, broad bands	1	58
8. Covered	17	75
Top of Quarry		
9. Middle nodular layer, coarse, porous, weathers with lumpy surface	3½	78½
10. This layer and lower layers are described by Smith (on p. 208 of the publication mentioned in note 5, to which the reader is referred)		

The two Pentamerus layers are very important stratigraphic key horizons. They are very persistent both in character as well as in thickness. On account of their massiveness and resistance to erosion they are likely to form escarpments and terraces similar to those made by the Engadine. Coming, as they do, almost in the middle of the Niagaran, they are valuable in giving the geologist a clue to the position of the otherwise confusing strata above and below. They can be traced across Drummond Island from Marblehead almost mile after mile. A splendid exposure may be studied in the northwest quarter of Section 3, T. 41 N., R. 7 E, three miles west of Marblehead. The upper Pantamerus layer is 6 feet thick and lies at an elevation of 630 feet above sea-level. Higher on the hill about 15 feet of the cherty, fossiliferous upper Manistique crops out.

Stalwart. — On the mainland outcrops are rare. At Stalwart in the northwest quarter of Section 30, T. 43 N., R. 2 E., outcrops appear which represent scattered portions of the Burnt Bluff from the upper nodular layer down for about 20 feet. It appears that the Pentamerus layers are responsible for the hill at Stalwart, for they protected it until very recently.

Both layers of *P. oblongus* crop out at Taylor's Mill in Section 20, T. 43 N., R. 1 E., the upper one at an elevation of 735 and the lower one at 715 feet. Both are about 7 feet thick, but the interval between them has thickened to about 13 feet. It is the same characteristic thin-bedded, white weathering, limestone found farther east. In Sections 11 and 12 of T. 43 N., R. 2 W., large blocks of Pentamerus layers were seen. One of the layers was in place on the section-line at an elevation of 790 feet above sea-level. In Sections 8 and 9 of T. 43 N., R. 3 W., both layers are present and crop out on both sides of the road. The elevation is approximately 770 feet above sea-level.

Scott quarry. — At Scott quarry in Section 29, T. 44 N., R. 4 W., the Pentamerus layer may be found in the sides of the hill just east of the crusher at an altitude of 835 feet, 95 feet below the top of the quarry. Only one layer was seen by the writer, but the white thin-bedded layers below it indicate that it is the upper one.

Upper Manistique. — The best place to study the upper Manistique is at Taylor's Mill in Section 20, T. 43 N., R. 1 E. Here it is 95 feet thick and practically the whole of it crops out. Fossils are abundant throughout. At Scott quarry the whole interval is also present, but the Engadine is missing. In the face of the quarry, 60 feet deep, a good opportunity is offered to study the character of the component layers and to search for faunules. On Drummond Island 20 feet of the topmost portion may be studied along the west side of the island below the ferry. In the southwest quarter of Section 26, T. 42 N., R. 5 E., a good cliff may be seen in which fossils are numerous and a great variety of species may be collected. Farther east scattered outcrops are numerous to Marblehead.

Upper Manistique in Ontario — In order to compare the

strata in Chippewa County with those in Ontario, two sections were chosen from those pictured by Williams (Fig. 25). They are the Campbell Bay section and the Manitowaning section. Unfortunately the Pentamerus layers do not appear in either section, although the assumed horizon is shown by the dashed line which is Williams' position for the base of the Lockport. The writer believes this line, if it represents the Pentamerus layers, should be placed considerably higher. The upper 30 feet of the Manitowaning section is the Engadine and serves to tie up the sections.

Racine. — The uppermost formation of the Niagara was named the Racine by Ehlers. It is equivalent to the Engadine described by Smith as "an extremely massive, hard, and very crystalline dolomite, distinctly bluish or mottled and streaked with blue." In Chippewa County this formation crops out better than any other and can be traced along almost mile after mile by following it occasionally into Mackinac County. It is responsible for the "Niagara Escarpment" in this part of Michigan. The line of outcrop is shown on the map (Fig. 27) and it will be seen that the westernmost outcrop is the one three miles east of Trout Lake. Here the full (?) thickness of about 55 feet is exposed with the base at 970 and the top at 1020 under the fire tower. At Maple Hill in Section 3, T. 43 N., R. 4 W., nearly the full thickness is again shown with the base at 955. Near Rockview four miles south of Pickford the full thickness of 55 feet may also be seen. For other outcrops the reader is referred to the map where the elevation at the base is also given for purposes of calculating the dip and strike.

Before we leave the Engadine one outcrop should be mentioned which is very exceptional. It is on the section-line road between Sections 10 and 11 of T. 42 N., R. 1 E. The dip of the formation, which is usally 40 to 50 feet per mile to the south, is reversed and very much steepened, for the rocks dip 30 degrees to the northwest. This may be due to a coral reef, but if this is so, it is the only one seen by the writer. More probably it is due to faulting, for the elevations of the Engadine masses farther east seem to be too high.

FIG. 27. AREAL GEOLOGY OF CHIPPEWA COUNTY, MICHIGAN

On Drummond Island the Engadine crops out over large areas on the southern fourth of the island. At Huron Bay and in the vicinity of Johnswood the largest outcrops are to be seen. The most accessible one lies south of the ferry along the west end of the island, where the whole thickness is present and the contact with the Manistique may be traced for several miles until it enters the lake just north of Crab Island.

The following composite section for Drummond Island was made after all the localities had been visited.

COMPOSITE STRATIGRAPHIC SECTION FOR DRUMMOND ISLAND

	Thickness in feet
Silurian System	
Engadine Formation	
1. Bluish grey mottled dolomite, extremely massive, hard, coarsely crystalline. Fossils not common, but in certain horizons *P. oblongus*, *Halysites*, *Favosites*, etc.	55
Manistique Formation (Upper Division)	
2. Grey and brownish-grey thin-bedded dolomite, weathers white, much chert so that disintegrated outcrop often resembles heaps of ashes, fine-grained to medium-grained texture, very fossiliferous	95
Manistique Formation (Lower Division)	
3. Upper Pentamerus layer, one massive layer of buff dolomite, weathers easily to yellow-brown and dark brown, coarsely crystalline, on outcrop dark-colored and irregular, filled with casts of *P. oblongus*	7
4. Pale, brownish-grey dolomite, weathers white, fine-grained, resembles Fiborn in texture, hard, thin-bedded	8
5. Lower Pentamerus layer, same as No. 3	7
Burnt Bluff Formation	
6. Upper nodular layer, cream-colored dolomite, weathers brownish, nodular and dark, coarse texture, porous, upper one foot is saccharoidal	7
7. Buff dolomite, fine-grained to medium-grained, thin-bedded and even-bedded	25
8. Middle nodular layer, dolomite like No. 6	5
Fiborn (?) member	
9. Grey and buff limestone, some lithographic texture, some medium-grained, all thin-bedded and even-bedded. Layers in upper part weather out white and with broad ribbon bands	15

	Thickness in feet
10. Covered interval	7
11. Lower nodular layer, dolomite like Nos. 6 and 8, except upper 18 inches, which is similar but saccharoidal	5
12. Grey to buff dolomite with thin dark, carbonaceous streaks (ribbon rock), hard, even-bedded, fairly massive, breaks into rectangular blocks	15
13. Brown dolomite, saccharoidal, massive	7
14. Ribbon rock, like No. 12, partly covered	25
Base of Burnt Bluff (?)	
15. Covered interval	35±
16. Grey and blue limestone, extremely massive, without apparent bedding planes, weathers into dome-like masses, very hard porous, silicified fossils (coral reef)	35±
17. Covered interval	15
18. Yellow dolomite, some chert in nodules, even-bedded, weathers deeply, *Favosites*, partly covered	45±
Ordivician System	
Richmond Formation	
19. Blue and grey limestone, calcareous mudstone, quite fossiliferous at many horizons	100±

University of Michigan

A NOVELIST IN LETTERS

HAROLD C. BINKLEY

IN 1740 Samuel Richardson was still an obscure London printer, earning a very good living at his trade and spending a large part of his income in playing the benign rôle of adoptive father to a household of sentimental girls. In a man already past fifty, there seemed little likelihood of his becoming anything further, unless it might be more benign and more adoptive. And then, quite by accident, and much to his own surprise, he found himself the famous author of a very popular novel. His reputation has lasted well, for although we do not often, in the manner of his day, give ourselves over to tears in reading of Clarissa Harlowe's sad fate, we continue to rate Richardson high among early English novelists. His decline in popularity is probably due to such change in taste as must inevitably take place in the course of two centuries, and to our modern lack of such leisure as the readers of his time were fortunate enough to enjoy; hardly, I think, to any fundamental failure in his art.

His first novel, *Pamela,* has just been called a chance product. It happened this way, to retell it in Richardson's own words: "For twenty Years I had proposed to different Persons (who thought the Subject too humble for them) that of Pamela; and it was owing to an Accident (the writing of the little Piece of Familiar Letters) that I entered upon it myself. And its strange Success at Publication is still my Surprise." [1] Such success must have pleased the little printer, for to satisfy the furor *Pamela* had excited, he wrote a continuation of that story and proceeded to two further works, both longer and more involved tales. Of the three, *Clarissa Harlowe* (1748) is now generally conceded to be

[1] From an unpublished letter to Aaron Hill, 26 Jan., 1746–47. (Cf. Dobson's *Samuel Richardson* [London, 1902], p. 27, n. 1.)

the most tolerable; and *Sir Charles Grandison* (1752) the least; though in Richardson's own day, the tragic end of Clarissa was almost more than his hyper-sensitive readers could bear, while Grandison was joyfully enshrined by the ladies as a sort of idealized carpet-knight, the embodiment of all masculine virtues.

One striking characteristic of these books is that they consist almost wholly of letters between the various characters. The narrative is tossed, we might say, from letter to letter, proceeding each time undeviatingly but slowly towards the conclusion. At first glance, this would seem to be an ineffectual way of carrying a narrative, and an equally laborious means of projecting character. How did Richardson come upon what Mrs. Barbauld, his earliest biographer, called "this most natural and least probable way of telling a story"? The novelist in a letter to his friend and correspondent, Aaron Hill, explained it in the passage which follows:

> . . . Mr. Rivington and Mr. Osborne . . . had long been urging me to give them a little book (which, they said, they were often asked after) of familiar letters on the useful concerns of common life; and, at last, I yielded to their importunity, and began to recollect such subjects as I thought would be useful in such a design, and formed several letters accordingly. And, among the rest, I thought of giving one or two as cautions to young girls circumstanced as Pamela was. Little did I think, at first, of making one, much less two volumes of it. But, when I began to recollect what had, so many years before, been told me by my friend, I thought the story if written in an easy and natural manner, suitably to the simplicity of it, might possibly introduce a new species of writing. . . . I therefore gave way to enlargement; and Pamela became as you see her.[2]

Such manuals of letter-writing as Richardson here refers to were not unusual in that day. In fact, letter-writing had long been one of the accomplishments of polite young people and constituted a definite article in the code of deportment. As early as the sixteenth century two extremely popular books on letter-writing had been issued: William Fulwood's *Enemy of Idleness* (1568) and John Day's *English Secretary* (1586). From that time on it was common to find such title-pages as these, which are selected at random.

[2] *Correspondence*, ed. Mrs. Barbauld, 1804. I, p. lxxiii.

The Academy of Complements new Refin'd; wherein Ladies, Gentlewomen, and Schollars, may accommodate their Courtly Practice with Gentle Ceremonies, Complemental Expressions, and forms of speaking or writing Letters, most in fashion . . . (1670; first published 1640)

The Secretary in fashion, or An elegant and compendious way of writing all manner of Letters . . . (1670)

The Gentlewoman's Companion, or A Guide to the Female Sex; . . . with Letters and Discourses upon all occasions. (1672)

A Flying Post, with a Packet of choice new Letters and Complements; containing variety of Examples of witty and delightful Letters, upon all occasions, both of Love and Business; and is of very great use and help to all such as have a desire to learn to endite and write letters after the best and most elegant manner now used in Court, City, or Country; being both pleasant and profitable. (1678)

The Compleat English Secretary, and newest Academy of Compliments; containing the true Art of indicting Letters for all Capacities, relating to familiar Conversation between Friends, Husbands and Wives, Children and Parents, Masters and Apprentices, Brothers and Sisters, etc. also Love Letters; with others of Trade and Business, in easy and plain stile. . . . (1697)

Such books have found a market down well into our own day, especially for the guidance of the socially ambitious. As for casual correspondence, of course, modern standards of literacy have perhaps given people more skill in expressing than substance to express.

The particular manual which set Richardson on his way to eminence as a novelist is no unusual volume — unless it be in the author's overstrong didacticism. He did in a sense change the emphasis by making the letter manual into a thinly coated textbook of conduct. For it was his own suggestion that he should instruct his readers "how to think and act in common cases, as well as indite."

When his little book ultimately appeared it had a wide popularity. Mrs. Barbauld attests that it was still a favorite book with the servants of her day, and not infrequently charmed the mistress when chance brought it within her reach. The individual letters show more than customary invention in the author's choice of occasions. He is strictly up to date in his

appeal. His letters were often personal in their tone, at times almost familiar; and to this he added an occasional narrative interest. For Richardson's own experience in writing letters had been from the right end; at the age of thirteen, he tells us, he became a professional secretary for the love-lorn females of his neighborhood; and more recently in his own house he had been able to observe at close range and in great variety the motions of the eighteenth century female soul. Upon these most practical of experiences was built his theory of familiar correspondence. It was, then, no mere whim of an aging man that he should turn his wisdom to account in a manual of the sort, and do it, in some respects at least, better than it had been done before.

Nevertheless, it is primarily the work of the moralist, to a less degree of the rhetorician, and hardly at all of the entertainer. To our taste it is too didactic in aim and prim in style.

We might well doubt whether this sort of volume can be credited with any share in the development of so free a form as the novel. In seeking a source for the epistolary mode in novel-writing scholars have scrutinized many claims. A long tradition of letters collected and published for their purely informative value has been mentioned as a possible source. The eighteenth century periodical, particularly the *Spectator*, has been urged. The dialogue novel has been thought by some to hold the key to Richardson's inspiration. Supposing with many critics that an author cannot come independently at a fresh and novel method of literary expression, one can still go no further here than to point out that the conception of the letter-novel became *less unlikely* through the presence of these other congenial forms. There is barely any evidence of a direct relation. When, however, the investigator is impelled to uncover more direct and positive origins he finds them surprisingly in Richardson himself; in the novelist's own account of the genesis of *Pamela*, which we have already mentioned. Clearly, for him, the novel issued spontaneously from his attempt to compile a formulary book.

It is true that volumes of letters compiled for one reason or another were very popular; indeed, before the novel took over the function of entertaining the public, they often attained to the

doubtful merit of being best sellers. In these collections it is occasionally possible to discover a thread of narrative sequence, especially among those fabricated simply to entertain. In such a series as that attributed to a Portuguese Nun,[3] to take an unusually clear case, there is a marked narrative and dramatic interest, though her five letters make too slight a volume to be called in any sense a novel. Nor is there any cumulative plot to them. What plot there is, is reminiscent and largely told by indirections. These *Letters of a Portuguese Nun*, moreover, may actually be genuine; but when "mad Margaret," Duchess of Newcastle, wrote her *CCXI Sociable Letters* (1664) she was plainly indulging herself in a literary exercise, fully conscious of the advantages and limitations of the form she was choosing. Her avowed intention was to present the humors of men in a series of letters or scenes. The serial picture of contemporary life thus created in such collections may have strengthened the letter form up to the point where writers who were determined to entertain above all things took letters as the physical framework of a fictional narrative.

The ease with which Richardson was at last able to bridge this apparent chasm is best explained by realizing that the Richardson of the *Familiar Letters* and the Richardson of *Pamela* were primarily alike in being moralists. The same considerations which led the one to advise his readers "how to think and act as well as indite," made the other append to *Pamela* the subtitle, "Virtue Rewarded." The calculating and sophistical code which Richardson seems to accept, much as it may offend our modern standards of virtue, was none the less his earnest creed and was generally subscribed to by his time. And the fact that he should have chosen and continued to use the novel as successor to the letter manual as a means to his cherished aim is at least a testimony to his good judgment and to his human love of success.

It would not be fair, however, to leave the impression that Richardson did nothing further to justify his reputation as a

[3] *Five Love Letters from* [Marianna d'Alcoforado] *a Nun to a Cavalier* [Chevalier de Chamilly]. Done out of French into English by R. L'Estrange. (1678)

novelist, than merely to write some highly moral tales for the edification of his time. That would be to rate him as an unhappy cross between Æsop and Louisa May Alcott. The novel with Richardson was a form of art, its aim was primarily to narrate, and however intent the author might be on driving home his moral, he was obliged here to leave it for his characters to do as forcefully but as gracefully as possible. As for his device of unfolding the story in letters, we have noted that it was a reversion to boyhood experiences. The method came spontaneously to him. Leslie Stephen distinguished well when he wrote that "Richardson's novels, indeed, are not so much novels put for convenience under the form of letters, as letters expanded till they became novels." [4] No one would suppose that Richardson felt the letter to be anything but the most natural form available, for he was not merely occupied in these books with an external device, but absorbed in the epistolary quality of the letters themselves. These stories are not so much a thing of physical plot as of psychological analysis to the extent that each character preserves his or her distinct style throughout. Thus the method possesses a peculiar laborious charm — a charm which is wholly lost by a hurried or casual reading. So closely also does the author observe the obligation to pursue his tale that it is generally conceded that *Clarissa Harlowe* is an organic whole, and for all its eight volumes, cannot be successfully abridged.

Aside, however, from Richardson's success with the epistolary novel, letters as a means of telling a story have serious disadvantages. The method was not generally adopted, though Richardson's experiment was repeated by Henry Mackenzie, Fanny Burney, Tobias Smollett, Sir Walter Scott, and Henry James, to mention the most notable examples. A letter in fiction, of course, has the value of a document, making more real the illusion. But this advantage is at once cancelled by the impossibility that minutely circumstantial letters on every occasion should have been written, and preserved, and should now form a connected narrative. Even Richardson, who took great liberties with his readers in this respect, was sometimes obliged

[4] *Hours in a Library* (London, 1899), I, 63.

to resort to the diary form to carry long sections of *Pamela* at such times as the unfortunate heroine was closely imprisoned by her urgent suitor, and occasionally to direct narrative in his own person. The improbability of the letter sequence was still more conspicuous in *Clarissa Harlowe* and *Sir Charles Grandison*, owing to the greater number of correspondents and the complexity of the pattern. In tacking back and forth from character to character in an attempt to reach the outcome, the effect was often loose and sometimes even incoherent.

In the second place the length of these romances in letters has often been urged against them, and certainly to our taste they are as bad as interminable. This, however, does not answer finally for the eighteenth century. And in defense Richardson has this to say in preface to *Sir Charles Grandison:*

> The nature of familiar letters, written, as it were, to the *moment*, while the heart is agitated by hopes and fears, on events undecided, must plead an excuse for the bulk of a collection of this kind. Mere facts and characters might be comprised in a much smaller compass: but, would they be equally interesting?

The adoption of the letter method led to a third infelicity; namely, the necessity of the *confidant* to whom the letters may be addressed and the plot unfolded. In novels as well as in the drama the *confidant* is too mechanical a figure to be truly plausible or very artful.

In defense of the letter form, Richardson himself has been the most eminent advocate. The improbabilities of the device he does not deny, though he seems always to be working tacitly on the assumption that there is really nothing to distract the reader's attention. We have noted his defense of their length. For the positive advantages of the epistolary mode he endorses the opinion of one whom he calls "an ingenious and candid foreigner."

> . . . It has given the author great advantages, which he could not have drawn from any other species of narration. The minute particulars of events, the sentiments, and conversations of the parties, are, upon this plane, exhibited with all the warmth and spirit that the passion supposed to be predominant at the very time could produce, and with all the distinguishing characteristics which memory can supply in a history of recent transactions.[5]

[5] *Clarissa Harlowe*, Postscript.

This seems to have been really Richardson's way of working, but in this very point of view there is a serious danger to the art of the novel. When Rousseau, for instance, adopted the letter form for his *Nouvelle Héloïse*, he picked from his day-dreams three personalities in whom he became so engrossed that he made them write to each other, and so built up his novel. Perhaps it was inevitable in Rousseau that he should deserve the accusation of Madame du Deffand that one and all the characters of his novel lose their identities to become the mouthpieces of Rousseau himself. That Richardson, then, should so clearly have preserved the identity of his characters is a distinct achievement.

How valuable then is this addition of the letter form to fiction? One student of the problem states the issue clearly in the following way:

> The letter form is not suited to all novels; but only to certain characters and situations. Where it succeeds in laying bare to us the depths of inner life, and in giving us fine psychological detail it is apt. It is not adapted to novels which demand the turbulent treatment of unsettled periods, bold deeds, and life rich in dramatic changes.[6]

This answers our question so far as it concerns the greatest of letter-novelists. Richardson is commonly labelled the first of the psychological novelists; and to this type of fiction his material and his method were admirably suited. An extended period of violent and dramatic action could not possibly be portrayed in truly familiar letters; there would be a basic incongruity between the texture of the material and the structural type. Conversely, there is a fortunate, and I am inclined to think, a supreme congruity between Richardson's letters full of detail, and the leisurely, unimpassioned, microscopic analysis of character and situation. It is possible to smile at the method, even to ridicule it. But the fact we must unequivocally face is that it was enormously successful and extravagantly praised by those other-minded people of the eighteenth century. Even in our day an occasional reader is fascinated by the immense leisureliness of these books into wishing, like Tennyson, that there were a great novel in hundreds of volumes, that one might go on and on.

University of Michigan

[6] Erich Schmidt, *Richardson, Rousseau, and Goethe* (Jena, 1875), p. 78.

A STUDY OF THE LAUGHTER OF THE PRE–SCHOOL CHILD IN THE MERRILL–PALMER NURSERY SCHOOL

ABBIE CRANDELL ENDERS

PHILOSOPHERS from the time of Plato and Aristotle down to the present have tried to decide what is the basis of laughter. Most of these philosophers, and more recently psychologists, have discussed laughter solely from the adult standpoint.

All agree that there is a large social element in laughter. Most psychologists believe that laughter is inherent in the human being (Darwin, McComas and Eastman), while a few, among them Hartley, maintain that it must be learned.

Authorities differ as to the elements in the situations that cause laughter. Some believe, as do Hobbs and Alexander Bain, that laughter is due to a feeling of superiority in contrast to another's infirmity or, as Hutcheson states, that the occasion of laughter is a contrast of dignity and meanness. Melland states, "the more a thing appears to us at once unusual on one side and familiar on the other, the greater is our tendency to laugh." Bergson says, "We laugh when something mechanical is incrusted on the living." He believes that "Laughter is above all a corrective." Hartley, Hall and Allin state that quick recovery from fear or apprehension is laugh-provoking. Many believe, Darwin, Sully and Angell, that laughter is primarily an expression of joy or happiness. Others emphasize the physiological basis. Spencer, Allin, Bruce and Sidis maintain that it is the means by which nature provides an outlet for surplus nervous energy. Similarly Bliss contends that "Laughter is the result of suddenly released repression, the physical sign of subconscious satisfaction."

While there is little agreement in the definitions, there is a great similarity in the statement of situations that cause the laughter of children. Fenton and Greig, in reviewing laughter-provoking situations as recorded in infant biographies, called attention to the social element. "The first smiles are almost always bestowed on people; they arise in response to familiar, friendly faces and voices" (Fenton, 1925, p. 242). Another common element in these situations that has not been observed is that of movement. Most of the time there is some movement of the child himself or of others or of things that stimulate the smile or laugh. Movement of the child himself, as when Mrs. Fenton's son was allowed to "kick unhampered" (Fenton, 1925, p. 240), or when Miss Shinn's niece was "tossed in the air, slid down one's knees, or otherwise tumbled about. . . . Swinging or tossing her into her mother's arms, or mine, . . . excited great hilarity" (Shinn, 1893, pp. 202–203). Often the faces that the child watched moved, as "in making a grimace" (Shinn, 1893, p. 16), or "When I suddenly uncovered my own face and approached his" (Darwin, 1877, p. 289), or "sudden reappearances of one's head" (Sully, 1896, p. 111), or "the laugh at the friendly nodding to him" (Preyer, 1892, p. 295).

Sound is often an element in producing smiles or laughter in infants, "a friendly voice" (Fenton, 1925, p. 240), or "a few caressing words" (Shinn, 1893, p. 239), or singing (Preyer, 1892, p. 295), "a rapid succession of sharp staccato sounds from one's vocal organs" (Sully, 1896, p. 411). Rasmussen (1920, Part I) records that he could always make his daughter laugh by asking, "Can you laugh a little for father," pitching his voice high.

Hall and Allin (1897, pp. 15–16) state that, "Most familiar animals, their forms, actions, and, it would seem, especially their noises are sources of great merriment for children. . . . Games that involve catching or grabbing are often very mimetic of animals, and are always hilarious."

Dr. Kimmins (1922, pp. 52, 95) states that, "Children of five and six are amused by action, noise and dramatic effects: someone falling down, funny dancing, bumping into each other,

grotesque faces and figures, things upside down and inside out, dressing up when they take funny parts, and funny sounds. . . . In a class of thirty-five children between six and six and a half, the selection of the funniest sights (arranged according to their frequency in producing laughter) were: Punch and Judy shows, jazz bands in the streets, dancing dolls in street, decorated cars in carnivals, sheep driven thru the street." All these situations contain the element of motion while some of them combine motion and sound. "Up to the age of seven humorous situations which cause laughter are almost entirely visual." This is partly true, but it disregards the large amount of laughter in children caused by their own joyous movements.

"Sounds which distress the adult delight the child." McComas (1923, p. 48) states that "motions, such as swinging, whirling on one heel, rising and falling on 'see saw', all stimulate the organs of balance. Running, jumping — all activities that aid the growing muscles — are accompanied with hearty laughter in the healthy child."

The experimenters in the field of laughter have followed three methods: (*a*) the questionnaire, used by G. Stanley Hall and Dr. Kimmins; (*b*) the use of pictures or stimulus words in which the subject states his reactions (pictures were used by Miriam A. Walker and M. F. Washburn, and by Lillien J. Martin; stimulus words, by Morgan, Mull and M. F. Washburn); (*c*) direct observation, by Darwin, Preyer, Rasmussen, Shinn, Moore, Dearborn, Perez, Greig and Fenton in the observation of the smiles and laughter of infancy.

The first two of these methods are inapplicable to the study of the laughter of the pre-school child. The last method, direct observation, was that followed largely in this study, which aims to ascertain what makes the pre-school child laugh. More specifically the phases studied were:

1. What makes a child laugh?
   a) Relation to things (motion, sound, and so forth).
   b) Relation to people (social element).
2. Do these things, or kinds of things, that make a child laugh, vary with age? Does the personal or social element vary with age?

3. Is the amount of laughter the same for two-, three-, and four-year-old children?
   Will the group of children of higher intelligence show any difference in the average amount of laughter as compared with the average amount of laughter of the group of lower intelligence?

The specific material used consisted of:

1. Toys
   a) Toys that move:
      (*a*) Scary Ann — press a button and her hair rises up.
      (*b*) Wallopus — An animal that moves down an incline with a jerky movement.
      (*c*) A doll — press down, and it springs up with a little squeak (used on only a few occasions).
   b) Toys without motion (no mechanical motion):
      (*a*) A wooden dog — can turn head.
      (*b*) Twistum — can twist into various positions.
2. Pictures
   a) A large picture (8 in. by 30 in.) in bright colors of a laughing dog, rabbit and duck.
   b) A picture of Wallopus in colors.
   c) A picture of six people (colored), slit and folding, so that the head, trunk or feet of one can be folded over onto the adjacent figure.
3. False faces
   a) A clown.
   b) An Indian.
   c) A funny man.
4. Games of dramatizing or any vigorous movements of hands or legs.

The method followed was largely that of direct observation of the children in their work and play throughout the nursery periods — from nine in the morning until one o'clock in the afternoon — noting (*a*) the name of the child or children; (*b*) the number in the group; (*c*) the duration and nature of the laugh; (*d*) the situation.

A second method was to take a child from the group, allow him to uncover toys one at a time; then note his reactions.

A third method was to present toys and pictures to the group and to note every individual child's reactions.

The method of choosing one child each day to be watched exclusively was tried and abandoned because: (*a*) rarely was

more material gained concerning the particular child; (*b*) much material regarding the other children was missed; (*c*) the data were too scanty to justify any conclusions.

PRESENTING TOYS TO INDIVIDUAL CHILDREN

This method proved to be the least fruitful. On the shelf were arranged five toys: a wooden dog, a monkey, Twistum, a doll and Scary Ann. A child was brought in, seated comfortably by the shelf. He was told that he might take the cover off "this," — as the examiner pointed to the first toy. The child removed the cover himself. He was allowed to examine the toy, play with it, and do anything he wished with it. His reaction to each toy was noted. After he had examined each one in turn, he was shown the large picture of the laughing bunny, duck and dog. It was soon discovered that this seemed to stimulate curiosity rather than laughter.

Since negative results were obtained for the most part, it was decided to present the toys to the children in a group and to note their individual reactions.

Two months later the same method of taking a child from the group and presenting him with certain toys was tried again, for it was thought valuable to find out if the social element in laughter was really as great as this preliminary trial indicated. The procedure was the same, the only change being that four toys were used instead of five. The doll and monkey were eliminated, the Wallopus was added. The picture was omitted also. The toys were presented to twelve children individually. It was apparent that the Wallopus caused more laughter than any of the other toys. Of the forty-eight possibilities for laughter, there were only sixteen laughs, eight of which were at the Wallopus. The Wallopus had already been presented to the group as a whole, by whom it was received with gales of laughter. What part of the laughter was due to the former pleasure experienced with the group, and what part to the motions of the toy, cannot be determined. The toy that ranked next in causing laughter was Scary Ann, the only other toy that had movement.

More laughter appeared this time than when this method was used two months earlier. Part of this was probably due to the fact that formerly the examiner was a stranger to the children while at this later period she was a familiar individual. Children who laughed frequently when in the group merely smiled when toys were presented to them individually. In no instance was the laughter in this situation as hearty as it was when the toy was presented in the group. This indicates that there is an important social element in the hearty laugh.

PRESENTING MATERIAL TO THE GROUP

The children were comfortably seated in a ring. At this time it was their custom to tell "news," that is, to show any toy or anything that they had brought from home and about which they wished to tell the other children. Since this was their custom, a new toy or picture presented to them by the experimenter or by the person in charge of the school proved to be no novelty. The presentation was simple; the toy or picture was always wrapped up or covered in some way, so that there was a moment of waiting when the attention of the children was centered on the thing about to be seen. This also introduced an element of suspense. The person that presented the toy was careful not to smile or laugh, or ask any leading questions.

When the Wallopus was presented first, a short poem was read about it and its picture was shown. Only one child laughed at the poem or the picture. This was one of the older children (who had the highest I. Q. in the school). When the Wallopus itself was presented the children watched it a minute, then burst into amused laughter, followed by hilarious laughter. Of the eight children present, two did not laugh but only smiled.

When the picture of the three laughing animals was presented, the children smiled but did not laugh. Their smiles showed that they were amused, but the picture was not laugh-provoking.

The Twistum was presented to the group; they looked at it curiously, asked questions, and four of the eight children chuckled a little when it was twisted into an absurd position.

Among those who laughed the ages were about equally distributed.

The false faces were presented, one at a time, and held up for the children to examine; a few smiled but none laughed. The false face was tried on by one of the group who bowed around to the children in a comical manner, causing them to laugh hilariously. The disguise with the added motion had a stronger effect than the disguise alone.

The toy that caused the most hearty and continuous laughter was one brought by a child. It was a dog made like a glove (so that by putting the hand inside the mitten or body part, extending the fingers into its head and front legs, the operator could move these members at will). George showed the dog to the children; there was no laughter. Then he was asked if he could show the children how it worked. He made the dog scratch his ear. The response was a simultaneous burst of hearty laughter lasting for a full minute. Then he made it bow — with the same result as before. Then the directress made the dog wave "bye-bye," and for the third time the children burst into a hearty, very resonant, high-pitched laugh lasting a full minute. (It is unusual for children's laughter, especially that of a group, to continue so long; it usually lasts about one fourth of a minute.)

The games that produced laughter were always those involving free motion. Dramatizations of Humpty Dumpty and Jack and Jill were usually laugh-provoking, especially when Humpty Dumpty fell off the wall or Jack and Jill fell down the hill. This was usually even more amusing to the chief actors than to the audience, which was very noticeable when the game had been played several times in the same week. The audience no longer laughed but merely smiled, while with one or two exceptions the actors continued to laugh, particularly when they fell down. A finger play, made up of various motions ending in a vigorous twirling of the hands and arms, which the children entered into with great abandon, invariably produced hearty laughter.

Running, galloping, and more especially jumping to fast music always caused some — and usually most of them — to

laugh. At the end of the music to which the children gallop they stop, each uttering a loud "Whoa." This sound, combined with the enjoyment that they had been experiencing from the free movement, usually caused many chuckles.

DAILY OBSERVATION

The method that yielded the most results was that of daily observation of all the children at their work and play in the nursery. A daily chart was posted in the nursery for recording the following data: (*a*) the name of the child, (*b*) the number in the group, (*c*) the duration and the nature of the laugh, and (*d*) the situation. The results of this method are shown on the chart at the end.

The children's names were arranged according to age. After each child's name were recorded the date of his birth, his I. Q., and the number of days that he was present. In the next two columns were entered the number of times that he laughed and his average each day; then the number of times that motion or sound entered into the situation. Motion and sound were each redivided into (*a*) motion, or sound, of the child himself, and (*b*) motion or sound caused by other persons or things. This was followed by the number of situations that produced laughter when neither sound nor motion was involved. Then was recorded the number of times that the child laughed when he was (*a*) with another child or children, (*b*) with adults, or (*c*) alone.

RELATION OF INTELLIGENCE TO AMOUNT OF LAUGHTER

Six children showed average intelligence or slightly above, and six showed a marked degree above average. Both groups averaged about the same amount of laughter each day. The higher group showed a slightly higher average. This difference was too small to be significant.

Comparisons of Averages:

I. Q. Average	*Average Number of times each group laughed*
112.5	1.48
138.6	1.62
	14

RELATION OF AMOUNT OF LAUGHTER TO AGE

In arranging the children in three age-groups, an interesting difference in the amount of laughter was noticed.

Number of times each child laughed each day:

	Age 2 years	*Age 3 years*	*Age 4 years*
	1.00	1.21	2.76
	1.99	.68	1.28
	2.56	1.25	1.49
		.65	2.71
		.90	1.55
		2.07	2.44
		.73	4.00
		1.71	
Average	1.85	1.15	2.32 (or 2.05 with last child omitted)

General average 1.72 (1.68 with omission indicated above)

The averages of the number of times the three age-groups laughed each day were: (1) 1.85 times for the youngest group; (2) only 1.15 times for the middle group; (3) 2.32 times for the older group. The last child in this group was present only nine days and laughed an unusually large amount. She probably weights the average too much. With her eliminated the average for the oldest group is reduced to 2.05 times a day. The middle group showed an average of 0.53 less laughs than the average of all of the children.

This middle group, the three-year-olds, laughed less than either the younger or the older children, the two- and four-year-olds. There were too few of the younger children to make this conclusion significant. Further, it will be noticed that in this middle group there was only one child that laughed on an average of more than twice a day, while in the older group, four, or over half of them, laughed on an average of more than twice a day. Again, all the children that laughed less than an average of once a day are in this middle group. There were fifteen children in these two older groups, so the results, while not conclusive, indicate a real difference in the age groups.

MOTION AS AN ELEMENT IN PRODUCING LAUGHTER

a) Motion of Self

Out of 828 times that the children laughed, motion was an element in the situation 627 times, or 75.72 per cent of the time. In 50.82 per cent of the times, some motion of the child himself stimulated the laugh. These laugh-provoking situations involving motion of self were running (chasing one another), skipping, jumping and galloping to fast music. Others involving balance and motion such as teetering, climbing and swinging, riding tricycles, especially over an obstacle causing a bump, and falling, if it did not produce tears, usually provoked laughter. In most of these situations quick or sudden motion was involved. The laugh usually immediately followed the motion instead of occurring simultaneously with it.

b) Motion of Other Persons or Things

Watching the motions of other persons or things stimulated laughter just half as often (24.88 per cent of the time) as did motion of the child himself. Here, the situations that caused laughter in the watcher were essentially the same as those that caused laughter when the child himself was the actor. The motion, however, usually was more sudden or more novel and it was not so certain to cause laughter as was the same or similar motion of the child himself. The laugh-provoking power wore off sooner for the child who watched the action than for the child who acted. This was apparent, as stated before, in the dramatization of Humpty Dumpty and Jack and Jill.

SOUND AS AN ELEMENT IN PRODUCING LAUGHTER

The second element that seemed to be present in a large number of laugh-provoking situations was that of sound (sounds made by the child himself or caused by other persons or things). Sound did not prove as great a factor in producing the laughter of young children as did motion. It was a factor in the situation 11.60 per cent of the time. In many of the situations, sound was

combined with motion, such as the clatter of beads, or blocks falling to the floor.

The beginning of word-play appeared among the older children. They laughed at the sound of the words "egg souffle" (calling it "egg shoefle.") "dumb-bell," "Achen Drum," "Tin Jee Jee" and "Lily of the Valley." One day at lunch a group at one table started to cry, "Drink your cocoa," "Drink your milk," "Drink your dress," "Drink your hair ribbons." They continued greatly amused until they were stopped in order to finish their dinner. One day two of the older children, aged five years one month (the only five-year-old in school) and four years nine months, were pumping together in the swing. The older child started, "Mamma hair, Mamma teeth," and laughed an amused laugh. The other child joined in the laugh, either repeating after the former just what she said or adding something new, and they continued, "Mamma lips," "Mamma stomach," "Mamma turkey feathers," and so on. Then came, "Daddy window," "Daddy stone," "Daddy eyelashes," "Daddy Dicky Campy," and the like. The children were not stopped and they continued with this word-play and chuckling for fully eight minutes. It was unusual for amusement and laughter to last over such a long period. The making of senseless rhymes, which usually appears in the six-year-olds, was not observed among the nursery school children.

MISCELLANEOUS SITUATIONS

In the situations that involved neither motion nor sound, many of the laughs were due to achievement; the chuckle of pleasure followed the completion of some piece of work, or when a child hurt himself slightly, as when he pounded a finger, dropped a block on the toe, or was pinched between tables, and so on. There was usually a moment of apprehension after the slight hurt followed by a short laugh. A number of cases were due to children seeing and hearing others laugh, joining in the laugh for the sheer joy and companionship afforded.

THE SOCIAL ELEMENT IN LAUGHTER

Of the 828 times that the children laughed, 743 times, or 91.6 per cent of the time, they were with one or more children; 42 times, or 5.07 per cent of the time, they were with an adult; 43 times, or 5.19 per cent of the time, they were alone. Over half of these instances (24 out of 43) when the child laughed while alone belonged to one child, Tommy, aged two years ten months. By eliminating this one child, the percentage of times children laughed while alone is reduced to 2.30 per cent.

Tommy's laugh was excited, high-pitched and often terminated in a shriek. It signified his excited reaction to being with so many children. The nature as well as the amount of Tommy's laughter gradually changed as he adjusted himself to the group. Tommy's case illustrates a kind of laughter that is often observed in children, especially in those who seldom play with children of their own age, the excited high-pitched laughter, due to excitability and overstimulation, often heard at parties. Adults wrongly conclude from this that children laugh a great deal. In the nursery school where the children were more accustomed to working and playing together, this excited laughter soon settled down into a calm amused laugh which varied in amount from day to day and in different individuals, but on the average was only 1.72 times a day.

In the daily life of the nursery school, laughter occurred much more frequently when two were playing together than in the sum of all the other combinations. This was probably due to two factors: (*a*) that children tend to play together in groups of two; and (*b*) that a group of two furnishes a more intimate relationship than a larger group.

CONCLUSIONS

(1) Both groups of children — those with average and higher intelligence — laughed practically the same number of times each day.

(2) An interesting difference in age groups appeared; the middle group, the three-year-olds, showed an average amount of

laughter, less than either the younger or older group. The youngest group, however, was too small to furnish material for any significant comparison.

(3) The social or personal element in laughter appeared to be the same for all the children from two to five years of age. They laugh most frequently when playing with other children (91.67 per cent of the time). They seldom laughed when with adults or alone.

(4) Sound and motion, or the combination of the two, were the most effective elements in the stimulating of laughter of young children.

Motion was present in the laugh-provoking situations 75.72 per cent of the time. Motion of the child himself was twice as effective in producing laughter as was watching motion in other persons or things.

(5) Motion and sound were present in the laugh-provoking situations of all the children from two to five years of age. There was, however, a slight difference in the actual situations that caused the laugh. The tumbling down of a tower of blocks, or the clattering to the floor of beads, was more certain to cause laughter among the two-year-olds than among the older children. The beginning of word-play was found more frequently among the older children.

While sound was an element that stimulated the laughter of small children, motion was an outstanding element.

In conclusion I wish to acknowledge my indebtedness to the Merrill-Palmer School for making the study possible; to Dr. Helen T. Woolley, now of Columbia University, and to Dr. Lelah M. Crabbs, Merrill-Palmer School, for their direction and encouragement; and to Professor Pillsbury for his helpful suggestions.

Merrill–Palmer School and
University of Michigan

TABLE

Summary of Results

February 15 — May 25, 1926

Children	Born	I.Q.	Number of days present	Number of Laughs	Average laughter each day	Motion		Sound		Miscel.	With other child or children	With adults	Alone
						Self	Other things	Self	Other things				
A	Feb. 4, 1924		32	32	1.00	15	5		2	14	25	5	2
B	Aug. 3, 1923		27	51	1.99	21	17	2	8	11	34	9	8
C	June 10, 1923		34	87	2.56	43	43	0	14	19	62	1	24
D	Dec. 30, 1922	117	43	52	1.21	34	12		3	10	50	1	1
E	Nov. 6, 1922	119	28	19	.68	9	5		0	4	19		
F	Nov. 3, 1922	105	24	30	1.25	17	8	1	0	9	21	5	4
G	Aug. 21, 1922	137	23	16	.65	9	5		1	7	15	1	
H	July 14, 1922	143	20	18	.90	11	6	1	2	3	17	1	
I	May 26, 1922		28	58	2.07	28	9	1	3	9	52	5	1
J	Feb. 22, 1922	139	7	12	1.71	9	1	2		3	11	1	
K	Feb. 15, 1922		22	16	.73	10		1	2	4	15	1	
L	Nov. 14, 1921	148	17	47	2.76	20	10	3	5	17	44	2	1
M	Oct. 13, 1921	132	29	37	1.28	25	8	2	1	5	33	3	1
N	Aug. 12, 1921	117	37	55	1.49	19	13	4	5	19	54		1
O	Aug. 6, 1921	115	38	103	2.71	56	23	5	5	25	102	1	
P	Aug. 6, 1921	102	31	48	1.55	30	7	3		12	48		
Q	June 8, 1921	133	45	111	2.44	50	22	4	8	27	106	5	
R	Apr. 12, 1921		9	36	4.00	15	12	4	4	9	35	1	
Totals	18 children		494	828	172	421	206	33	63	208	743	42	43
						627		96					
Averages			27.44			75.72%		11.60%			91.67%	5.07%	5.19%*

* 2.30% with C (Tommy) eliminated

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THE OPTIMUM NUMBER OF READINGS BEFORE INTRODUCING READING–RECITATION IN LEARNING*

SOLOMON GROSSMAN

INTRODUCTION

A GREAT deal of work has already been done on the factor of recitation in learning. This work, notably by Katzaroff, Kuhn, Witasek and Gates, points to the general conclusion that recitation, if introduced after a few preliminary readings, leads to the most economical and effective learning.[1] By recitation is meant a combination of attempted recall plus prompting. The exact point, however, at which it is best to introduce recitation into the learning process has not been satisfactorily demonstrated. Although Gates found that, for nonsense material, the more quickly attempts at recitation are introduced after a preliminary reading period of one minute and forty-eight seconds the better the results, his findings are not conclusive. In the first place, he did not carry his methods for enough; i.e., his graphs show 20 per cent reading and 80 per cent recitation to be the best method, but he does not give the results of the next method (10 per cent reading and 90 per cent recitation). Another criticism is that the method of presenting the nonsense syllables upon a card is very conducive to unintentional recitation during the readings; he did not sufficiently control the factors of testing and prompting during the readings. Finally, he did not control the tempo of learning, which earlier work has shown to be a very

* The work reported in this paper was done in the Psychology Laboratory, College of the City of Detroit.

[1] Gates, A. I., "Recitation as a Factor in Memorizing," *Arch. of Psychol.*, No. 40, Sept., 1917. This paper contains summaries of the work of the other authors mentioned.

important factor in determining the effectiveness of recitations. In general, however, the evidence points to the conclusion that recitations should be introduced early.

In view of these criticisms, it is the purpose of this experiment to determine more specifically, if possible, the optimum time to introduce recitations into the learning process.

SUBJECTS, MATERIALS, PROCEDURE

The subjects were all adults and, with one exception, trained in psychology. There were five men — E. B. S., M. C., S. G., H. L., W. H., — and three women — E. S., R. G., M. L. Subject E. B. S. had had a great deal of training in learning nonsense syllables. The remaining subjects, with the exception of R. G., were students who had had training in psychology but no experience with nonsense syllables. Subject R. G. had no training whatsoever in psychology.

The learning material was exposed by means of a Shepard–Wirth exposure apparatus. A series of eight nonsense syllables, chosen because it could not be learned in one reading and yet would not take unduly long to memorize, was so arranged upon the drum as to require twenty-one seconds to complete one reading. Each syllable was shown for one second and one second intervened before exposures of succeeding syllables. The remaining six seconds were taken in passing from the last syllable back to the first. This tempo was selected because it proved to be slow enough to enable the subject to read the syllable easily and fast enough to discourage anticipation. The learning was done individually at approximately the same time each day and under apparently the same physical conditions. The subject was required to sit before the exposure apparatus and repeat aloud each syllable as it appeared at the window. He was told to make it a "straight reading," i.e., he was not to anticipate the syllables or in any way group them. After he had completed the required amount of reading he was immediately asked to recite, and to repeat the syllables aloud and also to spell them. As he recited, the syllables were exposed so that he might correct himself or prompt himself if he had forgotten them. After each

recitation, in order to eliminate the feeling of hurry and to minimize inhibitions, he was required to relax for a period of thirty seconds during which time he was not to test or repeat the syllables to himself. In this way the recitations were continued until he could give the whole list perfectly without any prompting.

The learning was carried on under four methods representing four different numbers of readings before recitation: (1) one reading, (2) three readings, (3) five readings, and (4) seven readings. In order to assure maximum attention the subject was never told the method by which he was to learn. A complete introspective report was asked of each subject.

In judging the efficiency of each method, two criteria were used, namely, the total time spent in learning and the time of last recall. The time of last recall gives some indication as to "how well" the learner learned; it furnishes some criteria of how well the subject will retain the learned material, though it is by no means a positive indication. Table I shows the total of times spent in learning; Table II, the time of last recall.

TABLE I

Total Time of Learning

The number of records upon which the averages are based are shown under the heading N. Time records are expressed in seconds.

Subjects		Method I 1 reading, 21″		Method II 3 readings, 63″		Method III 5 readings, 105″		Method IV 7 readings, 147″	
	N	Mean	M. V.	Mean	M. V.	Mean	M. V.	Mean	M. V.
E. B. S.	10	417.6	89.0	383.0	56.4	430.2	91.4	469.90	132.1
M. C.	8	295.62	59.9	273.0	78.7	293.0	53.0	293.62	52.8
E. S.	6	209.16	41.2	164.25	19.2	190.16	33.3	193.40	15.2
R. G.	6	325.16	87.5	259.28	82.6	317.16	61.1	319.8	30.6
M. L.	6	369.0	86.8	321.4	58.4	397.6	93.1	348 75	63.6
S. G.	10	339.4	90.7	245.3	34.5	276.0	70.0	330.50	75.1
H. L.	6	292.1	91.1	302.6	48.8	262.8	56.1	317.30	65.0
W. H.	6	410.5	89.1	363.0	69.0	295.5	60.0	412.30	57.1
Average		332.31	51.8	288.98	53.52	307.80	55.38	336.94	56.27

TABLE II

TIME OF LAST RECALL

Subjects	Method I		Method II		Method III		Method IV	
	Mean	M. V.	Mean	M. V.	Mean	M. V.	Mean	M. V.
E. B. S.	40.33	6.22	37.00	5.2	49.80	10.6	41.5	11.00
M. C.	33.85	9.22	32.62	5.12	33.62	5.22	31.37	5.46
E. S.	26.00	1.66	33.87	11.56	45.66	11.33	37.6	7.92
R. G.	35.83	9.11	31.57	5.79	35.50	3.33	33.8	6.48
M. L.	45.60	9.76	38.00	2.00	39.20	11.92	33.5	4.25
S. G.	53.20	10.80	41.33	4.88	48.30	12.36	45.8	9.36
H. L.	27.80	4.16	24.50	4.00	27.30	4.43	29.00	6.33
W. H.	32.60	4.33	27.60	4.33	27.60	3.00	31.00	5.0
Average	36.90	7.26	33.31	4.24	38.37	7.36	35.44	4.63

A study of the total of times reveals that introducing recitation too early or too late into the learning process is decidedly disadvantageous. In only one case, that of M. L., did the total time under Method IV show itself to be better than under Method III. The group averages, which are fairly reliable, as shown by the small relative mean variations, reveal the advantage of Method II and the decided disadvantage of Methods I and IV.

The times of last recall, given in Table II, which are an indication of how well the material was learned, show Method II to be the best, although there are individual variations. The individual averages prove that in 62 per cent of the cases Method II leads to the best results. The group averages are fairly conclusive as to the advantage of Method II.

Table III gives some indication of the percentage of the total time spent in reading and recitation in the method which gives the best results.

TABLE III

Subject	Method	Reading Percentage	Recitation Percentage
E. B. S.	II	16	84
M. C.	II	23	77
E. S.	II	38	62
R. G.	II	24	76
M. L.	II	19	81
S. G.	II	26	74
H. L.	III	40	60
W. H.	III	35	65
Average		28	72

Tables IV and V show the practice effects both in terms of total of times and in terms of the number of recitations. The expressions "1st half" and "2d half" in the tables refer to the first and second fifty per cent of the records.

TABLE IV

PRACTICE EFFECTS: TOTAL OF TIMES

Subject	Method I		Method II		Method III		Method IV	
	1st half	2d half	1st half	2d half	1st half	2d half	1st half	2d half
E. B. S.	464.6	370.6	406.8	359.2	446.8	413.6	576.8	363.0
M. C.	326.0	265.2	309.0	241.7	323.0	225.5	307.7	279.5
E. S.	245.6	172.6	162.5	166.0	192.6	187.6	192.6	194.5
R. G.	365.0	285.3	322.7	174.6	361.6	272.6	316.6	324.5
M. L.	424.3	286.0	373.3	243.5	414.6	372.0	409.5	288.0
S. G.	377.0	301.8	125.4	265.2	323.4	222.4	366.6	294.4
H. L.	362.6	221.6	333.3	268.6	282.0	143.6	328.3	306.3
W. H.	478.0	343.0	392.0	334.0	334.0	257.0	433.6	391.0
Average	380.38	280.16	303.12	256.6	334.75	261.78	366.46	305.15
Percentage of difference	73		84		78		83	

TABLE V

PRACTICE EFFECTS: NUMBER OF RECITATIONS

Subject	Method I		Method II		Method III		Method IV	
	1st half	2d half	1st half	2d half	1st half	2d half	1st half	2d half
E. B. S.	6.8	6.0	5.6	4.8	5.0	5.8	6.4	3.8
M. C.	7.0	4.7	5.0	3.7	5.2	3.0	3.5	3.0
E. S.	4.6	3.0	2.5	2.0	2.0	1.3	1.3	1.0
R. G.	6.6	4.0	4.5	2.6	4.0	3.3	4.0	3.5
M. L.	7.4	5.5	6.0	4.0	6.3	4.5	5.0	3.0
S.G.	5.0	4.0	5.0	3.5	3.2	2.4	3.4	2.8
H. L.	6.3	4.6	5.2	5.0	4.3	3.6	3.6	4.0
W.H	8.0	7.6	8.0	6.6	6.0	3.6	6.3	5.6
Average	6.48	4.92	5.22	4.02	4.5	3.31	4.18	3.33
Percentage of difference	75		77		73		79	

From Tables IV and V it is quite evident that there are marked practice effects, yet the relative effects for each method are for all practical purposes the same and hence do not invalidate the results.

INTROSPECTIVE DATA

Careful introspective reports were taken at the end of each learning and a study of these data reveals several interesting facts. The introspections suggest that the results of Method I are not due to any learning as such during the reading, but to a "holding over" of the impressions of the syllables, i.e., the data reveal that most mistakes are made in the latter part of the first recitation. They suggest also that during the recitation the subject recited from the "hold over" after-images which faded

out shortly after the first recitation was begun. This leads us to conclude that very little imprinting is accomplished in one reading and that the learning follows from subsequent recitation. All the subjects report that just one reading is highly inadequate and merely serves to enable them to "get acquainted" with the syllables. They report that "real learning" seems to begin when they commence to recite; at that time they localize and correct their mistakes.

With subject E. S., Method IV appears to be disadvantageous because she had learned the syllables long before seven readings were completed; the continued reading merely acted as a distraction. Subject S. G. also reports a tendency for the attention to flag after a few preliminary readings.

The introspections reveal the interesting fact that it is almost impossible to get a "straight reading," especially in Methods III and IV. There was reported a tendency to anticipate and test oneself and this becomes especially strong when the number of readings is relatively great. It is interesting to note that the fewest mistakes were made in the first and last syllables of a series. There is also a decided tendency for these syllables to "hold over" and to be anticipated. This accounts, perhaps, for the fact that they are learned first.

Meanings or any other unusual features about the syllables make the learning more rapid, while syllables that are more or less difficult to pronounce and have strange sounds prove harder to learn.

In a study of the time of each recitation, it is noticed that the times do not gradually decrease but tend to increase up to a point after which there is a marked decrease until learning is complete. The introspections suggest the conclusion that the times increase while the syllables are being localized and that the decrease in time begins when the subject becomes fairly confident that he knows the syllables.

CONCLUSIONS

(1) With nonsense syllables readings are decidedly subject to a law of diminishing returns.

(2) For efficiency, as here considered, the introduction of recitations too early or too late is a great disadvantage.
   a. The best place to introduce recitations is after three preliminary readings. This gives the best results both for economy of time in learning and degree of learning as measured by the time taken in the last (correct) reading-recitation.
   b. In terms of percentage time, the results show that devoting 28 per cent of the total time to reading and the remainder to recitation leads to the best results as here considered.

(3) Our results agree substantially with those of Gates, Kuhn and Witasek.

College of the City of Detroit
Detroit, Michigan

DESTRUCTION OF ERYTHROCYTES IN THE BLOOD BY ACIDS ABSORBED FROM INTESTINE

EPHRAIM B. BOLDYREFF

THE acidity of the gastric juice of higher animals as it is secreted from the gastric glands is about 0.5 per cent HCl, or approximately three times greater than the optimum acidity required for peptic digestion. Such high acidity at the beginning of digestion is needed not so much for the digestion of food as for its disinfection.

Dr. W. N. Boldyreff has proved, and it is now generally accepted, that in the normal organism during digestion, as well as in the empty stomach, the gastric acidity is regulated by the alkali of the pancreatic juice regurgitated from the duodenum into the stomach. The partial neutralization thus effected usually lowers the gastric acidity to 0.15 per cent HCl.

It was also shown experimentally in Boldyreff's laboratory at the Imperial University of Kazan by Dr. N. A. Milovzoroff that the acidity of the gastric contents is quite low when it reaches the small intestine. Often it is found to be as low as 0.05 per cent in the upper part of the jejunum.

The almost complete neutralization of acids, as mentioned above, in the small intestine is quite significant. The intestine tolerates hydrochloric acid in concentration of about 0.15 per cent, and therefore the further neutralization is not necessary for the prevention of irritation of the intestinal mucosa. Possibly the absorption of acids from the intestine by the blood is harmful for the organism. The presence of acids in higher concentration in the stomach is not harmful because there is no absorption of aqueous solutions from the fundus of the stomach.

On the other hand it is known that some acids have a destructive effect upon the red blood corpuscles and are used in laboratory practice as their solvent (acetic acid, for instance, in the pipette method of leucocyte count). Therefore, hypothetically, one could expect to find the same condition produced by acids in the animal body, after elimination of the neutralizing agency of pancreatic juice.

The effect of acids absorbed from the intestine on the red blood cells was studied in strong healthy dogs. The whole length of the intestinal tract was used for the experiments and the same phenomena were invariably observed. The possible neutralization of the acids in the intestine by the alkali of the pancreatic juice was excluded. One dog had both pancreatic ducts ligated and also had the intestines tied below the pancreatic ducts and at the caecum, two dogs had Thiry-Vella's fistula and one dog had the large intestine tied at the caecum and at the end of the rectum. The following acid solutions were used: natural gastric juice, 0.5 per cent HCl, 0.8 per cent acetic acid, 1.25 per cent lactic acid and lemon juice. On dogs with Thiry-Vella's fistula the experiments were carried out under normal conditions (the dogs were operated on over two years ago). Two other dogs were under anaesthetic (40 per cent chloretone in 40 per cent alcohol) during the experiments. The quantity of acid introduced into the intestine varied from 100 to 200 c. c. The decrease in the number of erythrocytes was usually noticed in from $1\frac{1}{2}$ to 4 hours after the acid was introduced and absorbed from the isolated part of the intestine. The decrease of erythrocytes was from 1,000,000 to 2,000,000. The number of red blood cells is restored to normal rather slowly. Below are tabulated changes in the number of erythrocytes in one of the experiments due to absorption of lemon juice from the Thiry-Vella's isolated loop of small intestine.

CHANGES IN NUMBER OF ERYTHROCYTES DUE TO ABSORPTION OF LEMON JUICE

160 c. c. of fresh lemon juice were introduced into the isolated loop of the small intestine

Kind of experiment	Normal	Number of hours after						
		2	4	6	8	20	24	77
Number of erythrocytes....	4,980,000	5,050,000	3,090,000	3,280,000	3,670,000	3,800,000	3,790,000	4,770,000

The recently obtained data show that lactic acid absorbed from the isolated loop of the small intestine produces considerable decrease of the erythrocytes in blood. The control experiment on a dog with gastric fistula showed no material change in the red cell count. The double amount of acid was introduced into the stomach in this case, but the neutralizing agency of pancreatic juice was not excluded.

The ligation of the pancreatic duct alone is apt to produce the decrease of erythrocytes.

Further investigation of the destruction of red blood cells by acids absorbed from intestine is being continued. The changes in erythrocyte count due to absorption of lactic acid and ligation of pancreatic ducts are at present under investigation.

Pavlov Physiological Institute
Battle Creek Sanatarium
Battle Creek, Michigan

THE NORTHWARD DISTRIBUTION OF VENOMOUS SNAKES IN MICHIGAN

CHARLES W. CREASER

THE establishment of the exact distribution of poisonous snakes is a matter of first importance. The swamp rattlesnake or massasauga, *Sistrurus catenatus catenatus* Rafinesque, seems to have the most northward distribution of all venomous snakes in Eastern North America. It is the only poisonous snake of which we have a definite record for the state of Michigan. Recent collections and records have established a range for this species which includes a considerable area hitherto usually thought to be free of all venomous snakes.

It seems advisable to call attention to the presence of this poisonous snake in northern Michigan in order that any erroneous impression of the harmlessness of snakes in this region may be dispelled and that collectors and others may use the same caution in this region that they use in others well known to be infested with such snakes.

The range of the massasauga is given as follows by Stejneger and Barbour (1923): "Range: western New York, through Ohio to Nebraska, northward into Michigan and Ontario, southward to Kansas." Dr. Blanchard (1924, p. 48) gives its range as "Southern peninsula of Michigan, Ontario, and western New York, southwest to Kansas." Dr. Ruthven (1912) lists a specimen as far north as the Au Sable River in Oscoda County. This record has led to the conclusion that this river marked the northward limits of this snake in Michigan, and from this evidence it is frequently stated by zoölogists that there are no poisonous snakes north of this river in Michigan. During the summer of 1926 (August), however, it was discovered that this snake is very abundant on Bois Blanc Island, which is in Lake Huron just off

the north shore of Cheboygan County, Michigan. One adult specimen was collected and is now in the University of Michigan Biological Station collection. Many more were reported by various people. Telephone line workmen reported killing eight in putting up a short line on the island. Mr. Robinson, a summer resident of the island for the past twelve years, reports that they have been very abundant throughout this time. The life-saving station guards report seeing and killing them very often. Rattles from a large adult were observed that were certainly collected before 1916, and very likely correctly attributed to this island. Hence, this is no very recent extension of range. The island is low and swampy in places with some limestone outcrop.

The massasauga may be looked for in or near its favorite habitat in swamps in almost any region in the Lower Peninsula of Michigan and probably in the Upper Peninsula, although it has not been collected in that region as yet. This snake has always been regarded as a rare snake in Michigan except in the southern third of the state. Collections and reports, however, make certain that while the region to the north does not have as many favorable habitats, nevertheless this snake is usually locally abundant wherever it occurs in any part of the state.

College of the City of Detroit
Detroit, Michigan

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FURTHER NOTES ON THE FISHES OF THE GREAT LAKES AND TRIBUTARY WATERS

CARL L. HUBBS AND C. WILLARD GREENE

I. INTRODUCTORY

THIS paper has been prepared in order to call attention to new discoveries which have a bearing on the nomenclature or status of the fishes of the Great Lakes fauna. It comprises a set of additions and corrections to the senior writer's recent check-list.[1] The species and subspecies of *Notropis* which have been confused with *Notropis deliciosus* are discussed in greatest detail (Section III).

At the end of the paper the fishes of this fauna are again listed, in the numerical order employed in the paper quoted. This is done to bring the recent changes into line with the published list, and to indicate which of the author names should be included in parentheses (these parentheses were, in violation of the rules, all omitted in the previous contribution).

The fish fauna of the Great Lakes and tributary waters comprises, according to the present list, 158 species or a total of 180 forms, subspecies included.

II. MISCELLANEOUS NOTES

In his monograph of the Great Lakes Coregonidae, now in press, Dr. Walter Koelz is recognizing subspecies of several of the Great Lakes species of *Leucichthys*. These are given in due sequence in the appended list. *Leucichthys cyanopterus* is interpreted as a subspecies of *L. nigripinnis*. The name of *L. zenithicus* was mispelled in the 1926 Check-list (p. 12).

Salmo clarkii lewisi Girard (the Yellowstone, cut-throat, mountain or black-spotted trout of the northern Rockies) is now

[1] *Univ. Mich. Mus. Zoöl., Misc. Publ.*, No. 15, 1926, pp. 1–77.

being planted in Michigan. The supply of eggs was obtained by Mr. Fred Westerman in Flint Creek, Deer Lodge County, Montana. Although this is a Columbia River tributary, the race can provisionally be referred only to *S. c. lewisi*, because the scales are fine and the black spots are rather sparse anteriorly. Whether this form is native to Flint Creek, or was introduced from the eastern side of the Continental Divide, is unknown to us. This trout cannot now be added to our faunal list, because we have as yet no actual evidence of the success of the attempted introduction.

The brown trout of Europe should perhaps be known as *Salmo trutta* Linnaeus instead of *Salmo fario* Linnaeus (see Jordan, *Copeia*, No. 155), but we hesitate to accept this change until the systematic status of the various European trout is more clearly known.

The generic name *Megastomatobus* Fowler was inadvertently given as *Macrostomatobus* in the 1926 Check-list (p. 19).

On account of the slight differentiation of the western subspecies, *sucklii*, the common sucker of the East should be given trinomial designation, *Catostomus commersonnii commersonnii* (Lacépède).

The new subspecies described in the Check-list (p. 39) as *Notropis heterodon richardsoni* Hubbs and Greene proves on new evidence to be specifically distinct from *heterodon*. The junior writer took the two forms together during the summer of 1926 in Blake Creek, a tributary of the Little Wolf River, in Wisconsin, but they showed here no tendency to intergrade. The senior author, by further studies at the National and Field Museums, has been able to trace the form *richardsoni* completely into *Notropis nux* Evermann, a species originally described from Texas but occurring also in Oklahoma, Arkansas, Missouri, Iowa, Minnesota, Wisconsin, Illinois and Indiana. In northern Illinois, northeastern Iowa, southern Minnesota and across southern Wisconsin *Notropis nux* is represented by a fairly well defined northern subspecies *N. nux richardsoni*, which is distinguished by having the lateral line incomplete, the teeth of one or both inner rows often reduced from two to one, the eye less

than one third as long as the head, and the anal rays nearly always seven in number. Intermediate types occur in northern Indiana and in Illinois and Iowa. Farther south the species has a complete lateral line, the teeth consistently 4, 2–2, 4, the eye more than one third as long as the head, the snout sharper and the anal rays various — 8 in some localities, 7 or 8 in others and usually 7 in some. *Notropis nux* has often been confounded with *heterodon* in the northern half of its range, and has even been confused with *bifrenatus* in Indiana (by Evermann and Clark). Gilbert's unnamed variety of *heterodon* from southern Indiana, very recently assigned a new name by Jordan and Evermann,[2] is probably referable to typical *N. nux nux*. The confusion of these forms has been very natural, because it is only through the study of many series that one is able to show that the form *richardsoni* does not intergrade with *heterodon*, with which it has been found to occur, but that it is connected by intermediate races with the more distant yet fully as dissimilar form *nux*.

Notropis heterodon (for which a binomial name must again be employed) ranges west to southern Minnesota and eastern North Dakota.

Notropis gilberti is a common species in southwestern Michigan. It occurs also in the Ohio drainage basin in Pennsylvania, for *Notropis keimi* Fowler[3] proves on examination of the type and other local material to be inseparable from *gilberti*. It has even gotten into New York state, where Paul R. Greeley has lately secured examples in the Genesee basin. (See also pp. 380–381.)

Notemigonus crysoleucas should not, in our opinion, be divided into more than the two generally recognized subspecies, *crysoleucas* and *bosci*. We therefore do not follow Fowler[4] in referring the Great Lakes form to a subspecies *hemiplus*. Incidently we see still less occasion for the recognition of a distinct species (*seco*) in Texas — another suggestion made by Fowler in the same paper.

[2] *Hudsonius aletes* Jordan and Evermann, *Proc. Calif. Acad. Sci.*, 16, 1927, p. 502.

[3] *Proc. Acad. Nat. Sci. Phila.*, 1908 (1909), p. 533, pl. 27.

[4] *Proc. Acad. Nat. Sci. Phila.*, 76, 1924, p. 414.

Ameiurus melas is represented in the Great Lakes by the "typical" subspecies, *A. m. melas* (Rafinesque). This is quite different from the southwestern form, *catulus*, which Hubbs and Ortenburger are showing (paper in press) to be a representative of *melas* rather than of *nebulosus*, as generally supposed.

Leptops olivaris may now be included without doubt as a member of the Great Lakes fauna. It occurs in the larger streams of southwestern Michigan. A specimen from the Grand River, taken near Grand Rapids, is mounted in the Kent Scientific Museum of that city. Another from about the mouth of the Kalamazoo River is in the Field Museum.

Anguilla rostrata, the common eel, is still extant in certain lakes in Kalamazoo County, Michigan: a noteworthy discovery made recently by L. A. Sager.

Hadropterus maculatus should in our opinion still be used to replace *H. aspro* of authors: we have yet no evidence of the occurrence of a second species of this type in southern Michigan. Some doubt about our interpretation of this name has been expressed in a suggestion that *Alvordius maculatus* Girard might have been based on the species subsequently made known as *Etheostoma güntheri* Eigenmann and Eigenmann. But we now find that *güntheri* is absolutely identical with *Imostoma shumardi* (Girard).

Hadropterus phoxocephalus has until now been known from Great Lakes waters only from McCormick's unconfirmed Ohio record. We are now able to authenticate the occurrence of the species in this basin, for the junior author in 1926 took a fine specimen in the South Branch of the Little Wolf River, a Lake Michigan tributary of Wisconsin.

The key to the forms of *Boleosoma* in the 1926 Check-list (p. 62) involves an error: the cheeks are usually scaled in *B. nigrum olmstedi*.

Poecilichthys exilis Girard: further work has corroborated our views as to the highly involved synonymy of this species. In the former discussion (1926, p. 67), however, we failed to note that the generic name *Hololepis* Putnam takes precedence over that of *Copelandellus* Jordan and Evermann.

Aplites salmoides, by some typographical slip, was accredited in the Check-list (p. 71) to Rafinesque rather than to Lacépède. Jordan is the author of *Helioperca* (p. 72).

Triglopsis thompsonii was originally spelled as here given.

III. FORMS CONFUSED WITH *NOTROPIS DELICIOSUS*

Two species of *Notropis*, *volucellus* and *deliciosus*, have ordinarily been confused under the name of "*N. blennius*" or *N. deliciosus*. A study of the available type specimens and of the type-descriptions indicates that the following names have been applied to these two species:

Moniana deliciosa Girard, *Proc. Acad. Nat. Sci. Phila.*, 8, 1856, p. 199 (Leon River, Texas). — The name *deliciosus* may be maintained for the species with which it has most generally been associated. We find that both species were included among the original types of *deliciosus*, but we select the one with seven anal rays as being the true *deliciosus*.

Hybognathus stramineus Cope, *ibidem*, 1864, p. 283 (Detroit River, at Grosse Isle, Michigan). — The types of this form belong to the same species as those of *deliciosus*, as here restricted.

Hybognathus volucellus Cope, *ibidem*, 1864, p. 283 (Detroit River, at Grosse Isle, Michigan). — The type specimens of *volucellus* are lost, but the original description and comparisons make it evident that they represented the distinct species which has generally been more or less confused with *deliciosus*.

Hybopsis missuriensis Cope, *Bull. U. S. Geog. and Geol. Surv. Terr.*, 1870 (1871), p. 437 (Missouri River, at St. Joseph, Missouri). — The original material shows clearly that this name was based on the local representative of the *deliciosus* type.

Hybopsis scylla Cope, *ibidem*, p. 438 (Red Cloud Creek, tributary to Platte River). — Although the types are lost, it is clear from the original description, and from the type-locality, that the name *scylla* was likewise based on a race of *deliciosus*.

Cliola chlora Jordan, *Bull. U. S. Geog. and Geol. Surv. Terr.*, 4, 1878, p. 791 (upper Missouri region). — The many types of *chlora* represent the same Great Plains form of *deliciosus*.

Notropis reticulatus Eigenmann and Eigenmann, *Amer. Nat.*,

1893, p. 152 (Fort Qu'Appelle, Assiniboia). — The holotype of *reticulatus* is referable to the same race.

Notropis buchanani Meek, *Bull. U. S. Fish Comm.*, 15, 1895 (1896), p. 342 (creek near Poteau, Oklahoma). — Two original specimens of *buchanani* represent the pale central subspecies of *volucellus*. They are deeper in body than any other examples of this subspecies which we have seen, but the fins are not so excessively elongated as in others.

Other names have been associated with this species, but these are either wholly unidentifiable (*Minnilus microstomus* Rafinesque, 1820; *Hybopsis lineolatus* Agassiz, 1863) or wrongly so identified (*Hybopsis dorsalis* Agassiz, 1854; *Alburnops blennius* Girard, 1856).

The two species referred to are fairly easy to distinguish at any one locality, after one has learned the characters, but it is more difficult to state their distinctive features as exhibited throughout their ranges. The reason for this difficulty is that the two forms vary geographically in the same direction and also in the very characters by which the species themselves are differentiated. In both species, from the Great Plains toward the northeast the form becomes more slender and less compressed, the fins much shorter, the scales more numerous, and the lateral line scales less deepened. At any one locality *Notropis volucellus* has longer and sharper fins than *deliciosus*, the scales slightly fewer and the lateral line scales conspicuously deeper. But far northern races of *volucellus* have the fins shorter, the scales as numerous and the lateral line scales but little more deepened than in more southern forms of *deliciosus*. In Texas, oddly, both species are represented by races approaching the northeastern subspecies.

Wherever they are known to occur together, however, the two species may be distinguished by the number of anal rays, 8 in *volucellus* (rarely 7, not infrequently 9), 7 in *deliciosus* (very rarely 6 or 8). The fin-rays are weaker and more slender in *volucellus*, and the whole texture of the body more delicate. Color differences are also evident, though less trenchant; *N. volucellus* shows a more solidly and brilliantly silvery sheen, appearing to

be covered with a polished rather than a dull silver finish. Oddly in the south *volucellus* is vastly paler than *deliciosus*, whereas in the north the reverse is true, for there *volucellus* shows, especially after preservation in formaldehyde, more dark pigment than does *deliciosus*.

So closely do the northeastern races of *volucellus* and *deliciosus* resemble each other, and so unlike are the extreme subspecies of each species, that one cannot wonder at the fact that the species have so generally been confused. It was only after the study of scores of series, usually of many specimens, that we have finally been able to distinguish these races, and to trace each by steps into its more southern form.

Notropis deliciosus should probably be divided into at least three subspecies. The northeastern form (*Notropis deliciosus stramineus*) was correctly delimited by the senior writer in 1926 (pp. 37 and 43). The more southwesterly form *N. d. missuriensis* (*missuriensis = scylla = chlora = reticulatus*) corresponds with the account of *Notropis deliciosus deliciosus* as given in the Check-list, with this exception, that the series from Big Creek, Elgin County, Ontario, is referable to *volucellus* (the examples from Turkey Lake, Indiana, are typical of *missuriensis*). The typical (that is, first-named) subspecies *deliciosus*, ranges from the Red to the Rio Grande, that is, from southern Oklahoma to eastern New Mexico; it is intermediate between *missuriensis*, which ranges throughout the Great Plains region, and the northeastern form *stramineus*.

Notropis volucellus is represented by at least two subspecies. Typical *N. v. volucellus*, of which we have examined a good series of topotypes from Grosse Isle, ranges through the Great Lakes drainage basin from western Pennsylvania to Wisconsin and Minnesota and occurs also in the Mississippi drainage basin of Wisconsin. Intergrades occur in western Wisconsin and southeastern Minnesota. It differs from the more southern form, *Notropis volucellus buchanani*, of which we have specimens from southern Ohio, Kentucky, Kansas and Oklahoma, in the thicker and more slender body (depth 4.5 to 5.5 instead of 3.6 to 4.7 in standard length), the thicker and more bluntly rounded snout,

the shorter fins (length of depressed dorsal less than or only about two thirds as long as distance from dorsal to occiput and decidedly less than half as long as distance from dorsal to tip of snout); pectoral not nearly reaching to pelvic; the less elevated lateral line scales (anteriorly $2\frac{1}{2}$ to $3\frac{1}{2}$ instead of about $3\frac{1}{2}$ to $4\frac{1}{2}$ times as high as long), the scales more numerous (35 to 38, not 31 to 35), and the dark pigment more extensively developed. The Texas form, oddly, appears to be nearer typical *volucellus* than *buchanani*.

In typical *N. v. volucellus* there is a more distinct dark lateral band than in *deliciosus*. This fades out on the body anteriorly but reappears on the snout. The incipient development of the lateral band, together with a distinctly greenish color tinge, in fact gives the subspecies in life an appearance intermediate between that of *N. deliciosus* and that of *N. heterolepis*. The mid-dorsal dark streak is usually less solid than in *deliciosus*. The secondary lateral streak which in *deliciosus* is narrow and courses along the side, above and close to but distinctly separated from the primary streak, is represented in *N. v. volucellus* by a wider and much more diffused streak, which grades more or less fully into the primary streak.

In *Notropis volucellus buchanani* the melanophores are very few and sparse. They are irregularly scattered over the snout, and only faintly mark off the scale margins on the upper sides. They cluster somewhat along the mid-dorsal line to form a rather indistinct streak and indefinite blotches behind the occiput, at front of dorsal, below the middle of this fin (this blotch is best developed), and before the caudal. The lateral band is represented by little more than a posterior streak; the lateral line pores are only faintly marked off by black spots. In brief the black pigmentation of *Notropis volucellus buchanani* may be expressed as a ghost-like transformation of the coloration of *N. v. volucellus* or of *N. deliciosus*.

Notropis volucellus buchanani is not represented in the Great Lakes region in fully typical form, but one isolated race seems to be distinctly nearer this subspecies than true *volucellus*. This is the form inhabiting Big Creek, Elgin County, Ontario (a

Lake Erie tributary), — a series which was wrongly referred to *Notropis deliciosus deliciosus* in the 1926 list (p. 43).

We therefore recognize two species of the *deliciosus* type, each with two subspecies, as inhabitants of the Great Lakes drainage basin. These are:

Notropis deliciosus missuriensis (Cope)
Notropis deliciosus stramineus (Cope)
Notropis volucellus volucellus (Cope)
Notropis volucellus buchanani Meek

IV. DATA FROM THE 1927 SEASON

While this paper has been in press, we have continued our studies on the fishes of the Great Lakes fauna. Some of the results of these studies may be interpolated here. The few additional changes in nomenclature required by this recent work are indicated in the list of species at the end of this report.

Material of *Moxostoma*, recently collected in Houghton Lake, Michigan, represents a large, rather deep-bodied type of *M. lesueurii*, very much like the Canadian examples mentioned in the Check-list as obviously representing *Catostomus lesueurii*. We think it probable that the large size and robust condition of these red-horses are the result of life in shallow, rich lakes. This and other similar evidence point to the correctness of our referring *Ptychostomus breviceps* to the synonymy of *Moxostoma lesueurii* (Richardson).

The type of *Gobio plumbeus* Agassiz, examined at the Museum of Comparative Zoölogy, is an example of the species which has been correctly assigned this name (*Couesius plumbeus*).

The typical subspecies of *Rhinichthys atronasus*, which differs from *R. a. lunatus* not only in having a larger eye, but also in the paler coloration and less conspicuous speckling and in having less red on the lateral band in the breeding males but more on the pectoral fins, which are largely bright pink in males, occurs in at least some of the tributaries to Lake Ontario. It is therefore to be added to the Great Lakes fauna, and to the list of Atlantic drainage basin types occurring in this fauna only below Niagara Falls.

Mr. John R. Greeley of Cornell University informs us that he has taken two forms new for the Great Lakes list in New York in 1927: *Margariscus margarita margarita* (Cope) in Buttermilk Creek, near Ithaca, and *Notropis procne* in Catherine Creek near Watkins.

Recent explorations in New York state have yielded much additional material of *Notropis bifrenatus* and *N. cayuga*. It now seems highly probable that these forms do not intergrade. The status of *bifrenatus* as a Great Lakes fish is fully confirmed by these recent studies. In the Museum of Comparative Zoölogy are specimens of this species which were collected by Putnam in Lake Champlain, at Bridport.

New material just received from Arkansas and Oklahoma, and to be reported on later, confirms our treatment of the *Notropis deliciosus — volucellus* complex. One lot from near the type-locality of *buchanani* fully connects the deep-bodied phase of that subspecies, represented by the types of *buchanani*, with the ordinary, less robust phase which is more generally met with. Another series, from an Ozark stream in Oklahoma, is almost typical *volucellus*, only slightly approaching *buchanani*. The northern subspecies, in fact, extends southwestward across the range of *buchanani*, probably occurring there in upland streams (*buchanani* is an inhabitant of the larger rivers and the adjacent creek mouths). The intergrades between the two forms are distributed in a somewhat mosaic fashion. It is quite apparent, however, that the intergradation is real and complete.

An examination of the many types of *Hybopsis dorsalis* Agassiz, at the Museum of Comparative Zoölogy, shows clearly that this species is the form later described from the same state by Jordan and Meek as *Notropis gilberti*. These types have 8 principal rays in the anal as well as in the dorsal fin; the snout long and rather pointed; the mouth large, low and horizontal, and therefore "protractile downward"; the teeth 4, 1–1, 4, and the coloration as satisfactorily described by Agassiz (except that no color now remains on the fins). The name *Notropis dorsalis* (Agassiz) consequently is to be abstracted from the questionable synonymy of *N. deliciosus* (where it has been resting, owing to uncritical

judgment), and is to be employed in place of *Notropis gilberti* Jordan and Meek.

Fowler and Carlson [5] have lately pointed out some characters which they thought distinctive of *Notropis keimi* Fowler, as contrasted with *N. gilberti* (= *N. dorsalis*). Since we also examined the types of both *keimi* and *gilberti*, and came to the conclusion that the two are synonymous, a renewed comparison of the forms must now be made. Our examples of "*keimi*," from New York state, are not slenderer than *dorsalis* (depth 4.4 to 4.5 in "*keimi*"; 4.3 to 4.7 in *dorsalis*), nor is the eye consistently larger (4.3 to 4.6 in "*keimi*," 4.1 to 5.0 in *dorsalis*) nor the dorsal rays fewer (8 in six examples of "*keimi*," as usually in *dorsalis*, which however has occasionally only 7 dorsal rays). We still see no grounds for the specific separation of *keimi* from *gilberti* (= *dorsalis*). It is possible, however, that average differences will be found in proportions or counts; if so, *keimi* might be retained as a subspecies.

Notropis nux richardsoni Hubbs and Greene has just been discovered in Michigan. Dr. Jan Metzelaar took a fine series, in company with a few of *Notropis heterodon* and many of *N. heterolepis*, in the Grand River just above Lansing. This record not only extends the range of the subspecies, of which they are typical, but also confirms our interpretation that it is specifically distinct from *Notropis heterodon*.

A study of Arkansas and Oklahoma material of *Notropis whipplii* shows that the typical form (the species was described from that region) differs considerably from the Great Lakes form, which should be known as *Notropis whipplii spilopterus* (Cope). Our form has usually 8 rather than 9 anal rays, and shows less sexual dimorphism.

We have reëxamined (at the Museum of Comparative Zoölogy) the type of *Alburnus rubellus* Agassiz, from Sault Ste. Marie, and find it to be, as generally supposed, identical with *Notropis atherinoides* Rafinesque.

We have employed Agassiz's name *frontalis* for the northern subspecies of *Notropis cornutus*, which is characterized by the

[5] *Proc. Biol. Soc. Wash.*, 40, 1927, p. 68.

great crowding of the predorsal scales. We have done so despite the fact that Agassiz expressly stated that the scales of the "back" in *frontalis* are as large as those of the side. We have thought it extremely improbable that the southern type (to which Jordan and Evermann assigned the name *frontalis*) occurs at the type-locality of *Leuciscus frontalis* (Montreal River, eastern shore of Lake Superior). The type specimen of *frontalis*, examined at the Museum of Comparative Zoölogy, is a breeding male, in which it is difficult to count the predorsal scales, but these are about 30, certainly more than 25. In another example identified by Agassiz as *frontalis*, collected in Lake Huron, we count about 33 predorsal scales. The type of *Leuciscus gracilis*, also from Lake Superior, belongs to the same subspecies, as it has about 38 predorsal scales. There can no longer be any doubt as to the pertinence of these names to the northern subspecies of *Notropis cornutus*.

A revision of the species of *Hybognathus* made by the senior writer, presently to be reported upon, has disclosed the fact that the form occupying most of the Great Lakes drainage basin is an undescribed species. This will be described as *Hybognathus hankinsoni* Hubbs. The species of the Lake Ontario watershed of New York has been identified with the Atlantic Coast form, *H. regius* Girard.

Considerable doubt must be attached to the systematic as well as the distributional status of the Great Lakes species of *Ictalurus* and "*Villarius*." We wish to investigate these forms further, and ask for aid in securing the specimens needed to solve these problems.

Our view that Lake Champlain, the type-locality of the old name *Pileoma semifasciatum* De Kay, lies in the zone of intergradation of *Percina caprodes caprodes* and *P. c. zebra*, is confirmed. A series of eight specimens seen in the Museum of Comparative Zoölogy, collected by Putnam at Bridport on that lake, bridges over the gap between these two forms. We therefore have additional reason to maintain the name *zebra*.

Cottogaster putnami Jordan and Gilbert is not, as has generally been supposed, identical with *Rheocrypta copelandi* Jordan. It is a distinct species, in fact the one described from another tributary of the St. Lawrence River as *Cottogaster cheneyi* by Evermann and

Kendall.[6] It differs from *R. copelandi* in having a deeper and more compressed body, a sharper and only moderately decurved snout and fully terminal premaxillaries, larger scales (in 44 to 51 rows [7] to end of hypural), stiff anal spines, the anal fin neither enlarged nor tuberculated in the breeding males, the air-bladder somewhat developed. It also differs from *R. copelandi* in several features of coloration: the lateral blotches are much larger; the first dorsal fin is dark-edged and marked with large dark blotches, located nearer base than margin of fin, on the interspinal membranes, becoming blacker forward; these blotches are especially blackened in the breeding males, in which the pelvics are black and the anal blackish. *Cottogaster putnami* is also distinguished by features of squamation. The scales are absent on the cheeks and breast and in a triangular area behind the pelvics; the greater portion of the mid-ventral line behind the pelvics, however, is occupied by a row of modified spiny scales (as in *Hadropterus*); a hard plate remains, also, between the pelvics, as does another before those fins. We regard some of these features as sufficient for generic distinction, and therefore suggest that *copelandi* be again referred to the monotypic genus *Rheocrypta*. The generic name *Cottogaster* Putnam goes with *C. putnami*, for the type-species, *Cottogaster tessellatus* Putnam = *Boleosoma tessellatum* Thompson (not of De Kay), is clearly conspecific with *putnami*. In fact Putnam's material served as the type of *putnami*, and Thompson had the same species.

As compared with *Cottogaster uranidea* (Jordan and Gilbert), *C. putnami* has the snout very much less pointed and produced, and the coloration very dissimilar.

Cottogaster putnami differs from *Imostoma shumardi* (with which it appears to have as much in common as with *R. copelandi*), in that the soft dorsal and anal fins have fewer soft-rays; the anal fin does not become markedly enlarged nor tuberculated in the breeding males; the anal fin, however, becomes blackish, and the pelvics black, in breeding males; all the interspinal membranes

[6] *Bull. U. S. Fish Comm.*, 17, 1897 (1898), p. 129, pl. 8, fig. 8, and in Jordan and Evermann, *Bull. U. S. Nat. Mus.*, 47, pt. 3, 1898, p. 2851.

[7] There are 44 to 51 rows in types of *putnami;* 51 in type of *cheneyi.*

(not only the most anterior and posterior ones) are blackened; the lateral blotches are less crowded and less vertically elongated anteriorly; the head is blunter and the squamation different — the scales are much better developed on the belly (this is especially true of the mid-line spiny platelets, which are very weakly, though as we now find obviously developed in *shumardi*); the specialized plate between and the one before the pelvic fins of *C. putnami* are not developed in *I. shumardi* (in some specimens of which, including the type, there are, however, a few scattered ordinary scales on the breast); the cheeks are scaleless, instead of being well covered with ctenoid scales (the opercles in both forms are scaled).

Our view that *Etheostoma güntheri* Eigenmann and Eigenmann is a synonym of *Imostoma shumardi* (Girard) has been confirmed by an examination of the types of each.

In drawing up the foregoing remarks on the genera and species of the *Cottogaster* group of darters, we have had before us (at the National Museum) the types of each of the nominal species involved.

The species of *Ammocrypta* are imperfectly treated in the current literature. *Ammocrypta beani* appears to be always very incompletely scaled, has the outer series of premaxillary teeth strongly enlarged and has distinctive color features. *Ammocrypta vivax*, now without good evidence regarded as a subspecies of *pellucida*, has the squamation nearly complete, the outer teeth of the upper jaw moderately enlarged and its own color marks. *Ammocrypta pellucida* may have the scaly area almost as reduced as in *beani* or almost as extensive as in *vivax;* in this form the outer premaxillary teeth are scarcely enlarged, and the special color features of the two other forms are lacking. The variation in the squamation has been taken to distinguish two subspecies, typical *pellucida* and a southwestern form, *A. p. clara.* We find, however, that at most localities throughout the range of *pellucida* the partially scaled forms, resembling or approaching *clara*, are in the majority. We therefore do not recognize any subspecies under *Ammocrypta pellucida.*

That *Hololepis* Putnam should replace the later name *Cope-*

landellus Jordan is fully confirmed by an examination of Agassiz's specimens of *Hololepis Barratti*, as these are the virtual types of the genus. These have the top of the head largely scaled over, toward the occiput. If *H. fusiformis* should be regarded as generically distinct, by reason of the scaleless upper surface of the head, a new generic name would be required for it.

The current reference of *Hyostoma newmanii* Agassiz to the synonymy of *Etheostoma blennioides* we regard as correct, after having examined the types in the Museum of Comparative Zoölogy.

The two-spine sticklebacks of Lake Ontario have the lateral plates markedly reduced in size, but mostly present. They therefore represent a race intermediate between *Gasterosteus aculeatus aculeatus* and *G. a. cuvieri*. Following a symbolism which we are adopting for intergrading races, this Lake Ontario form may be named *Gasterosteus aculeatus: aculeatus* Linnaeus × *cuvieri* Girard.

V. Revised List of the Fishes of the Great Lakes and Tributary Waters

PETROMYZONIDAE

1. *Ichthyomyzon* Girard
   1. *I. concolor* (Kirtland)
   2. *I. unicolor* (De Kay)
2. *Petromyzon* Linnaeus
   3. *P. marinus* Linnaeus
3. *Entosphenus* Gill
   4. *E. appendix* (De Kay)

POLYODONTIDAE

4. *Polyodon* Lacépède
   5. *P. spathula* (Walbaum)

ACIPENSERIDAE

5. *Acipenser* Linnaeus
   6. *A. fulvescens* Rafinesque

LEPISOSTEIDAE

6. *Lepisosteus* Lacépède
   7. *L. platostomus* Rafinesque
   8. *L. osseus* (Linnaeus)

AMIIDAE

7. *Amia* Linnaeus
   9. *Amia calva* Linnaeus

HIODONTIDAE

8. *Hiodon* Le Sueur
   10. *H. tergisus* Le Sueur

CLUPEIDAE

9. *Pomolobus* Rafinesque
   11. *P. chrysochloris* Rafinesque
   12. *P. pseudo-harengus* (Wilson)
10. *Alosa* Cuvier
   13. *A. sapidissima* (Wilson)
11. *Dorosoma* Rafinesque
   14. *D. cepedianum* (Le Sueur)

OSMERIDAE

12. *Osmerus* Linnaeus
   15. *O. mordax* (Mitchill)

COREGONIDAE

13. *Leucichthys* Dybowsky
   16. *L. artedi* (Le Sueur)
      16a. *L. a. artedi* (Le Sueur)
      16b. *L. a. albus* (Le Sueur)
      16c. *L. a. manitoulinus* Jordan and Evermann
      16d. *L. a. tullibee* (Richardson)
   17. *L. birgei* Wagner
   18. *L. nipigon* Koelz
   19. *L. reighardi* Koelz
      19a. *L. r. reighardi* Koelz
      19b. *L. r. borealis* Koelz
   20. *L. zenithicus* (Jordan and Evermann)
   21. *L. alpenae* Koelz
   22. *L. hoyi* (Gill)
   23. *L. johannae* (Wagner)
   24. *L. kiyi* Koelz
      24a. *L. k. kiyi* Koelz
      24b. *L. k. orientalis* Koelz
   25. *L. nigripinnis* (Gill)
      25a. *L. n. nigripinnis* (Gill)
      25b (= No. 26 of Check-list). *L. n. cyanopterus* Jordan and Evermann
      25c. *L. n. regalis* Koelz
      25d. *L. n. prognathus* (Smith)
14. *Coregonus* Linnaeus
   27. *C. clupeaformis* (Mitchill)
15. *Prosopium* Milner
   28. *P. quadrilaterale* (Richardson)

THYMALLIDAE

16. *Thymallus* Cuvier
    29. *T. tricolor* Cope

SALMONIDAE

17. *Oncorhynchus* Suckley
    30. *O. tschawytscha* (Walbaum)
18. *Salmo* Linnaeus
    31. *S. salar* Linnaeus
        31a. *S. s. salar* Linnaeus
        31b. *S. s. sebago* Girard
    32. *S. fario* Linnaeus
    33. *S. irideus* Gibbons
        33a. *S. i. irideus* Gibbons
        33b. *S. i. shasta* Jordan

19. *Cristivomer* Gill and Jordan
    34. *C. namaycush* (Walbaum)
        34a. *C. n. namaycush* (Walbaum)
        34b. *C. n. siscowet* (Agassiz)
20. *Salvelinus* Richardson
    35. *S. fontinalis* (Mitchill)
        35a. *S. f. fontinalis* (Mitchill)
        35b. *S. f. hudsonicus* (Suckley)

CATOSTOMIDAE

21. *Megastomatobus* Fowler
    36. *M. cyprinella* (Cuvier and Valenciennes)
22. *Ictiobus* Rafinesque
    37. *I. urus* (Agassiz)
23. *Carpiodes* Rafinesque
    38. *C. difformis* Cope
    39. *C. cyprinus* (Le Sueur)
24. *Catostomus* Le Sueur
    40. *C. commersonnii* (Lacépède)
        40a. *C. c. commersonnii* (Lacépède)
    41. *C. catostomus* (Forster)
25. *Hypentelium* Rafinesque
    42. *H. nigricans* (Le Sueur)
26. *Erimyzon* Jordan
    43. *E. sucetta* (Lacépède)
        43a. *E. s. oblongus* (Mitchill)
27. *Minytrema* Jordan
    44. *M. melanops* (Rafinesque)
28. *Moxostoma* Rafinesque
    45. *M. aureolum* (Le Sueur)
    46. *M. anisurum* Rafinesque
    47. *M. lesueurii* (Richardson)

29. *Placopharynx* Cope
    48. *P. carinatus* Cope
30. *Lagochila* Jordan and Brayton
    49. *L. lacera* Jordan and Brayton

CYPRINIDAE

31. *Cyprinus* Linnaeus
    50. *C. carpio* Linnaeus
32. *Carassius* Nilsson
    51. *C. auratus* (Linnaeus)
33. *Couesius* Jordan
    52. *C. plumbeus* (Agassiz)
34. *Nocomis* Girard
    53. *N. biguttatus* (Kirtland)
    54. *N. micropogon* (Cope)
35 *Erimystax* Jordan
    55. *E. dissimilis* (Kirtland)
36. *Erinemus* Jordan
    56. *E. storerianus* (Kirtland)
    57. *E. hyalinus* (Cope)
37. *Rhinichthys* Agassiz
    58. *R. atronasus* (Mitchill)
        58a. *R. a. atronasus* (Mitchill)
        58b. *R. a. lunatus* Cope
    59. *R. cataractae* (Cuvier and Valenciennes)
38. *Leucosomus* Heckel
    60. *L. corporalis* Mitchill
39. *Semotilus* Rafinesque
    61. *S. atromaculatus* (Mitchill)
        61a. *S. a. atromaculatus* (Mitchill)
40. *Margariscus* Cockerell
    62. *M. margarita* (Cope)
        62a. *M. m. margarita* (Cope)
        62b. *M. m. nachtriebi* (Cox)
41. *Pfrille* Jordan
    63. *P. neogaeus* (Cope)
42. *Clinostomus* Girard
    64. *C. elongatus* (Kirtland)
43. *Opsopoeodus* Hay
    65. *O. emiliae* Hay
44. *Notropis* Rafinesque
    66. *N. heterodon* (Cope)
    66.1. *N. nux* Evermann
        66.1a (= 66b). *N. n. richardsoni* Hubbs and Greene
    67. *N. anogenus* Forbes
    68. *N. bifrenatus* (Cope)
    69. *N. heterolepis* Eigenmann and Eigenmann
    69.1. *N. volucellus* (Cope)
        69.1a. *N. v. volucellus* (Cope)
        69.1b. *N. v. buchanani* Meek

69. 2. *N. procne* (Cope)
70. *N. deliciosus* (Girard)
    70a. *N. d. missuriensis* (Cope)
    70b. *N. d. stramineus* (Cope)
71. *N. boops* Gilbert
72. *N. dorsalis* (Agassiz)
73. *N. blennius* (Girard)
74. *N. hudsonius* (Clinton)
    74a. *N. h. hudsonius* (Clinton)
    74b. *N. h. selene* (Jordan)
75. *N. whipplii* (Girard)
    75a. *N. w. spilopterus* (Cope)
76. *N. ariommus* (Cope)
77. *N. atherinoides* Rafinesque
78. *N. photogenis* (Cope)
79. *N. rubrifrons* (Cope)
80. *N. cornutus* (Mitchill)
    80a. *N. c. chrysocephalus* (Rafinesque)
    80b. *N. c. frontalis* (Agassiz)
81. *N. umbratilis* (Girard)
    81a. *N. u. cyanocephalus* (Copeland)

45. *Ericymba* Cope
    82. *E. buccata* Cope
46. *Phenacobius* Cope
    83. *P. mirabilis* (Girard)
47. *Exoglossum* Rafinesque
    84. *E. maxillingua* (Le Sueur)
48. *Notemigonus* Rafinesque
    85. *N. crysoleucas* (Mitchill)
        85a. *N. c. crysoleucas* (Mitchill)
49. *Hybognathus* Agassiz
    86. *H. regius* Girard
    86. 1. *H. hankinsoni* Hubbs
50. *Chrosomus* Rafinesque
    87. *C. erythrogaster* Rafinesque
51. *Hyborhynchus* Agassiz
    88. *H. notatus* (Rafinesque)
52. *Pimephales* Rafinesque
    89. *P. promelas* Rafinesque
        89a. *P. p. promelas* Rafinesque
53. *Campostoma* Agassiz
    90. *C. anomalum* (Rafinesque)

AMEIURIDAE

54. *Ictalurus* Rafinesque
    91. *I. punctatus* (Rafinesque)
55. *Villarius* Rutter
    92. *V. lacustris* (Walbaum)
56. *Ameiurus* Rafinesque
    93. *A. melas* (Rafinesque)

93a. *A. m. melas* (Rafinesque)
94. *A. nebulosus* (Le Sueur)
95. *A. natalis* (Le Sueur)
57. *Leptops* Rafinesque
96. *L. olivaris* (Rafinesque)
58. *Noturus* Rafinesque
97. *N. flavus* Rafinesque
59. *Schilbeodes* Bleeker
98. *S. gyrinus* (Mitchill)
99. *S. exilis* (Nelson)
99. 1. *S. insignis* (Richardson) [8]
100. *S. miurus* (Jordan)

UMBRIDAE

60. *Umbra* Krämer
101. *U. limi* (Kirtland)

ESOCIDAE

61. *Esox* Linnaeus
102. *E. vermiculatus* Le Sueur
103. *E. niger* Le Sueur
104. *E. lucius* Linnaeus
105. *E. masquinongy* Mitchill
105a. *E. m. masquinongy* Mitchill

ANGUILLIDAE

62. *Anguilla* Shaw
106. *A. rostrata* (Le Sueur)

CYPRINODONTIDAE

63. *Fundulus* Lacépède
107. *F. diaphanus* (Le Sueur)
107a. *F. d. menona* Jordan and Copeland
108. *F. dispar* (Agassiz)
109. *F. notatus* (Rafinesque)

PERCOPSIDAE

64. *Percopsis* Agassiz
110. *P. omiscomaycus* (Walbaum)

APHREDODERIDAE

65. *Aphredoderus* Le Sueur
111. *A. sayanus* (Gilliams)

SERRANIDAE

66. *Lepibema* Rafinesque
112. *L. chrysops* (Rafinesque)
67. *Morone* Mitchill
113. *M. interrupta* Gill

PERCIDAE

68. *Perca* Linnaeus
114. *P. flavescens* Mitchill

[8] Recently taken by John R. Greeley in the Lake Ontario drainage basin.

69. *Stizostedion* Rafinesque
    115. *S. canadense* (Smith)
        115a. *S. c. griseum* (De Kay)
    116. *S. vitreum* (Mitchill)
    117. *S. glaucum* Hubbs
70. *Hadropterus* Agassiz
    118. *H. evides* (Jordan and Copeland)
    119. *H. maculatus* (Girard)
    120. *H. phoxocephalus* (Nelson)
71. *Percina* Haldeman
    121. *P. caprodes* (Rafinesque)
        121a. *P. c. caprodes* (Rafinesque)
        121b. *P. c. zebra* (Agassiz)
72. *Rheocrypta* Jordan
    122. *R. copelandi* Jordan
73. *Imostoma* Jordan
    123. *I. shumardi* (Girard)
74. *Ammocrypta* Jordan
    124. *A. pellucida* (Baird)
75. *Boleosoma* De Kay
    125. *B. nigrum* (Rafinesque)
        125a. *B. n. nigrum* (Rafinesque)
        125b. *B. n. olmstedi* (Storer)
    126. *B. camurum* Forbes
76. *Poecilichthys* Agassiz
    127. *P. camurus* Cope
    128. *P. zonalis* Cope
    129. *P. coeruleus* (Storer)
        129a. *P. c. coeruleus* (Storer)
    130. *P. jessiae* Jordan and Brayton
    131. *P. exilis* (Girard)
77. *Catonotus* Agassiz
    132. *C. flabellaris* (Rafinesque)
        132a. *C. f. flabellaris* (Rafinesque)
        132b. *C. f. lineolatus* Agassiz
78. *Microperca* Putnam
    133. *M. punctulata* Putnam
79. *Etheostoma* Rafinesque
    134. *E. blennioides* Rafinesque

CENTRARCHIDAE

80. *Micropterus* Lacépède
    135. *M. dolomieu* Lacépède
81. *Aplites* Rafinesque
    136. *A. salmoides* (Lacépède)
82. *Chaenobryttus* Gill
    137. *C. gulosus* (Cuvier and Valenciennes)
83. *Apomotis* Rafinesque
    138. *A. cyanellus* (Rafinesque)

84. *Helioperca* Jordan
    139. *H. incisor* (Cuvier and Valenciennes)
85. *Xenotis* Jordan
    140. *X. megalotis* (Rafinesque)
        140a. *X. m. peltastes* (Cope)
86. *Eupomotis* Gill and Jordan
    141. *E. gibbosus* (Linnaeus)
87. *Ambloplites* Rafinesque
    142. *A. rupestris* (Rafinesque)
88. *Pomoxis* Rafinesque
    143. *P. annularis* Rafinesque
    144. *P. sparoides* (Lacépède)

ATHERINIDAE

89. *Labidesthes* Cope
    145. *L. sicculus* (Cope)

SCIAENIDAE

90. *Aplodinotus* Rafinesque
    146. *A. grunniens* Rafinesque

COTTIDAE

91. *Triglopsis* Girard
    147. *T. thompsonii* Girard
92. *Cottus* Linnaeus
    148. *C. bairdii* Girard
        148a. *C. b. bairdii* Girard
        148b. *C. b. kumlieni* (Hoy)
    149. *C. cognatus* Richardson
    150. *C. ricei* Nelson

GASTEROSTEIDAE

93. *Eucalia* Jordan
    151. *E. inconstans* (Kirtland)
94. *Pungitius* Coste
    152. *P. pungitius* (Linnaeus)
95. *Gasterosteus* Linnaeus
    153. *G. aculeatus* Linnaeus
        153a. *G. a. : aculeatus* Linnaeus × *cuvieri* Girard

GADIDAE

96. *Lota* Oken
    154. *L. maculosa* (Le Sueur)

University of Michigan

PRELIMINARY REPORT ON A SPECIES CROSS IN RODENTS *MUS MUSCULUS* × *MUS WAGNERI*

CLARENCE COOK LITTLE

THE object of the present communication is to record a series of preliminary experiments on the crossing of certain color varieties of the tame derivatives of the house mouse (*Mus musculus*) with wild individuals of the Chinese mouse (*Mus wagneri*).

There are recorded only a small number of crosses between species of rodents. A number of specific crosses in mammals are listed by Babcock and Clausen in their textbook on *Genetics in Relation to Agriculture* (pp. 219–249). Among these the only rodent cross to be recorded as an actual experiment is that of *Cavia porcellus* × *Cavia rufescens* (Detlefsen, 1914). This cross will again be referred to when the agouti pattern in mice is considered in more detail.

The only report of crosses within the genus *Mus* is that between *Mus rattus*, the black rat, and *Mus alexandrinus* which appears to be an agouti color variety of the same general form. So far as has been recorded, there seems to be complete fertility between these two types and they are said to hybridize freely in nature. It is frankly doubtful whether we are here dealing with a true species cross. The whole difference between the two appears to be that which characterizes Mendelian color types and no more.

Within a comparatively short time both these forms have been removed from the genus *Mus* and have been placed in the genus *Rattus*.

There is a short note to the effect that Ivanoff has succeeded in crossing *Rattus rattus*, the black rat (formerly *Mus rattus*),

with *Rattus decumanus* (formerly *Mus norvegicus*), the gray or Norway rat. The color and nature of the single young one obtained suggest, however, that he was dealing with a case of a mistake in the paternity and that the *decumanus* female had been fertilized by a *decumanus* male before isolation.

DESCRIPTION OF *MUS WAGNERI*

Gates, 1926, has published on account of *Mus wagneri* in a paper on hybrids between the Japanese waltzing mouse and the ordinary color varieties of the house mouse.

Mus wagneri was described by Eversmann (1848) as follows: "Mus wagneri — M. supra caudaqua griseo-fuscus; subtus abrupte candidus; auriculis majusculis; verruca halucari lamnato; cauda quam corpus breviore."

He comments further on these characters and a translation given by Gates is as follows: "In color this mouse approaches nearest to the darker varieties of *Mus sylvatius*, from which, however, it can be clearly distinguished by other characteristics. It is about four times smaller, smaller than even *Mus minutus*, and hence one of the smallest mammals. The tail is considerably shorter than the body; the ears are comparatively longer and more hairy than those of *Mus sylvatius;* the thumb-warts of the fore feet have a distinct nail. The dorsal side of the body is of a grayish brown color, with a tendency toward reddish yellow; the ventral side as well as the feet are pure white; on the sides the two colors are rather sharply separated; the hairs of the under side are not bluish at their base as in *Mus sylvatius* but white throughout. The tail has about 19 or 20 vertebrae and about 130 scale rings; it is nearly uniform in color, grayish brown, both above and below, but somewhat lighter on the under side; it is somewhat more hairy than that of *Mus sylvatius*. The claws of all toes are white."

The specimens obtained by the writer were the survivors of a shipment of forty-four which were brought from Pekin under the personal supervision of Dr. Sheo Nan Cheer. Although the trip was a long and arduous one, thanks to his care, eleven mice survived to reach Ann Arbor. After their arrival three died.

Of the eight survivors four were males and four females. Three of the females have had young and all four males have sired living young by either *wagneri* females or by females of domesticated color varieties of *Mus musculus*.

The pure *wagneri* have given a total of 31 young of which 15 have lived to weaning age. Twenty-five have been sexed. There were 13 males and 12 females as close to equality as could be expected.

Because of scarcity of pure *wagneri* material the cross between them with *Mus musculus* has been made only in one way with *wagneri* males and *Mus musculus* females. There stocks have been used and have given the following results:

	Total	Males	Females
Dilute brown × *wagneri*	82	26	29
Pink-eyed brown × *wagneri*	26	16	9
Dilute brown agouti (blazed) × *wagneri*	36	15	16
Grand total	144	57	54

There has been a good deal of mortality among new-born young and the figures are, therefore, not as extensive as one would wish. There is, however, obviously no trouble in making the cross in at least one direction.

In the eight litters of pure *wagneri* young the average has been 3.88 per litter. This is distinctly lower than the average of any of the domesticated stocks used in the laboratory.

A number of backcrosses have been made between F_1 males and tame mouse (*musculus*) females. These have totaled forty-three young.

The cross involved three genes by which the dilute brown *Mus musculus* females used in the original cross and backcross differed from the *Mus wagneri* males. These genes are:

A^w — white bellied agouti which characterizes *Mus wagneri*.
a — non-agouti as in the dilute brown.
B — gene for the production of black pigment (*wagneri*).
b — gene for the production of non black (in this case brown) as in dilute brown.
D — gene for intensity of pigmentation as in *wagneri*.
e — gene for production of pigmentation as in the dilute browns.

The F_1 animals were therefore A^waBbDd in constitution and

the dilute browns were *aabbdd*. Eight classes of young are expected in equal numbers. They are listed below with the number obtained in each:

		Expected
Black agouti with white belly	5	5.4
Black non-agouti	12	5.4
Dilute black agouti white belly	4	5.4
Brown agouti white belly	3	5.4
Dilute black non-agouti	7	5.4
Brown non-agouti	4	5.4
Dilute brown agouti white belly	5	5.4
Dilute brown non-agouti	3	5.4
	43	43.2

There is no evidence of any kind for linkage. This is what would be expected if each of the genes in the dilute brown mice found an allelomorph in the *wagneri* mice located as these same genes are in *Mus musculus*. There is, of course, no evidence for linkage in *Mus musculus* between any of these genes. The excess of blacks and dilute blacks is interesting but cannot, with the observed numbers, be said to be significant.

EVIDENCE FOR INCOMPLETE DOMINANCE OF CERTAIN GENES

The genes *D* for intensity of pigmentation and *P* for dark-eyed degree of pigmentation described and analyzed by Castle and the writer in 1909 and frequently used in genetic experiments since then, have always been considered as being completely dominant over their allelomorphs *d*, dilute, and *p*, pink-eyed, respectively.

When, however, *wagneri* males are crossed with females of these two color varieties the resulting F_1 animals are distinctly different in the two cases.

F_1 animals $A^w aBbDdPP$ in formula are distinctly darker both in amount of black pigment in individual hairs and in the extent of heavily pigmented hairs down the flanks than are F_1 animals of the formula $A^w aBbDDPp$.

This suggests an interesting method of measuring incompleteness of dominance by the use of *wagneri* stock in crosses and by analysis and measurement of the distribution of pigment in the individual agouti hair and in the coat pattern as a whole.

It is also safe to assume that there is real reduction in pigment in animals *aaBbDDPp* as compared with those *aaBbDDPP*, although the fact that *a* distributed the pigment throughout the hair and over the whole coat makes it impossible to distinguish the difference in the non-agouti animals which are *DDPp* and *DdPP* in formula. This fact is important only as a preliminary method of analyzing the physiological interrelationships of genes during ontogeny.

PATTERN FACTORS

It is also noticeable that the bellies of the F_1 hybrids are not nearly so white as are those of the pure *wagneri*. There is frequently a distinct increase of dark pigment which produces at times a clearly outlined "vest" pattern extending from the front legs about half way to the hind legs in the form of a blunt V.

It is interesting in this connection to note that the Cavies produced in the hybridization experiments of Detlefsen had a distinct darkening due to weakening of the agouti factor, and the appearance of more "unticked" hairs in the coat. There is an analogy between the two cases.

These things suggest a difference in strength of the A^w gene in *wagneri*. It is as though it was used to doing its work over a small body surface, such as that of the minute *wagneri* mice and that the F_1 animals which are distinctly larger than *wagneri* — being about intermediate between them and the tame mice used — offered too large a field physically for the gene to cover in its activity. As a result it has not functioned equally over the whole ventral surface. This would produce regions in which the gene in development functioned causing a white condition like that of *wagneri* and other regions in which it failed to express itself so completely, thus producing dark areas due to the effect of the *a* (non-agouti) gene from the tame parent.

If these patterns have such an origin it will be interesting to see whether the reciprocal cross will produce any different results. A new and intensely interesting type of ontogenetic relationship during the development of genes may be involved in this case.

RATE OF MATURITY OF F_1 ANIMALS

Young have been sired by eight F_1 males. Their average age at breeding has been 76.6 days. Young have been obtained from six F_1 females. Their average age at breeding has been 122.5 days. This difference is so striking that it seemed for some time as though the F_1 females were sterile.

Something of the same sort seems to hold in the case of the pure *wagneri* raised in the laboratory. Three of the males raised here have sired young, but none of the females have given any young as yet although their average age is 153 days.

That a question of late maturity rather than seasonal factors is primarily involved is shown by the fact that litters of young have been recorded with great regularity from two of the four original *wagneri* females since October, 1926. At that time they had been in the laboratory for about one month.

There is apparently an interesting physiological difference between *wagneri* and certain of the tame derivatives of *musculus* in this respect. The latter mature very quickly and usually can be counted on to give females which become sexually mature more rapidly than do males.

This whole question will require investigation and is a promising line to follow.

In summarizing we may say:

(1) That *Mus wagneri* males cross readily with *Mus musculus* females.

(2) That the F_1 hybrids are intermediate in size and are fertile in both sexes.

(3) That the female F_1 hybrids appear to mature distinctly more slowly than their brothers.

(4) That this also seems to hold true for pure *wagneri* raised in the laboratory.

(5) That the genes *a* (non-agouti), *b* (non-black, i.e., brown), and *d* (dilute) segregate in the backcross generation between F_1 hybrids and tame dilute brown *musculus*.

(6) That the gene *P* (dark-eyed) is shown to be incompletely dominant over *p* (pink-eyed reduction) in the F_1 hybrids.

(7) That peculiar coat patterns appear in certain F_1, suggesting the possible existence of an ontogenetic factor or factors of great interest.

University of Michigan

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STUDIES ON THE BIOLOGICAL EFFECTS OF RÖNTGEN RAYS ON MICE

I. PRIMARY GENERAL EFFECTS

JOSEPH M. MURRAY

THIS paper, the first of a series of reports presenting the results of experiments with Röntgen rays on an inbred race of brown mice, will list the primary general effects observed and outline briefly the method of approach by which it is hoped that more definite information regarding the biological action of these rays may be gained.

In the grossly observable effects are included arbitrarily the changes in general appearance, growth, nervous control and reproduction. Histological changes in the tissues are still under observation and will be reported at a later time. To establish the normalcy of the treated mice, the growth curves and other observable factors are being carefully compared with those of stock and control animals.

Material for the experiments was taken from a stock of brown mice which has been inbred in these laboratories for seven years. All the stock mice have been produced by sister to brother mating through twelve generations, being direct descendants of male No. 57 and female No. 52, control mice used by Little in a previous work (1).

These mice are large, hardy, vigorous and very tame. Their coat color is solid brown with usually a white ventral patch of variable size and also a variable amount of white on the tail. With the exception of an abnormal jaw,[1] which appears to be lethal at time of birth, no abnormalities have been so far observed.

[1] This appears to be the jaw abnormality "j" recorded by Little and Bagg (1).

The stock animals were mated in the fall of 1925 (October 24, 1925), 29 females divided among 7 males in carefully recorded matings. All the males and 27 of the 29 females proved fertile. The females produced young when at an average age of 116 (115.9) days. The youngest reproduced at 73 and the oldest at 172 days of age. The average number of young for these first litters was 6.63. One of the females died before reaching reproductive age and the remaining female was apparently sterile to the males with which she had been tested up to one year of age. Over 2100 young have been born as descendants of this stock.

All exposures to the Röntgen rays were given under the deep therapy tube in use daily at the University Hospital of the University of Michigan. This is a Coolidge tube which is kept standardized at 135,000 volts, 5 milliamperes, 9 inch spark gap. With this arrangement, at 30 cm. target distance and without filter, the tube produces a human erythemal dose in two minutes. (We are indebted to Dr. Ernst Pohle and his assistants who have kindly aided in the detail of irradiating the animals.)

Mice to be irradiated were taken to the X-ray room in metal containers and placed beneath the area of direct rays. Control litter mates were removed after entering the exposure room and placed in a similar container but thoroughly protected from the rays. The animals received the irradiation over the entire dorsal surface. Immediately after the exposure the control mice were returned to the litter.

The litters of average size produced by this stock make it possible to pick litter mate-controls in most cases. We emphasize this point to show the distinction between control mice which are siblings of the exposed animals, while stock mice are brother or sister relations in other litters by the same group of parents.

In returning the X-rayed mice to the home pens great care was taken to make the young free from foreign odors. The mice were mixed in the bedding and the mother removed long enough to allow the pen odors to replace those contracted by handling or derived from the container and the X-ray room. In previous work where similar precautions were not taken, it was observed

that the excitement of the mother due to such unfamiliar odors on the young caused her either to neglect them all or to reject the weaker ones entirely, and thus cause an otherwise avoidable mortality. We have been fortunate in nearly all the exposed litters and are quite certain that mortality and poor nursing due to this cause have been very low.

All the animals used in these experiments were kept as nearly as possible under similar feeding and housing conditions. At first indication of pregnancy the females were segregated in a maternity pen. The mice in each litter were observed on the day of birth. On the second day after birth the individual mice were marked by a system of brands and their initial weights taken. All weighing was done before exposures were given. Each individual was weighed at two-day intervals during the first thirty days. At this age the litters were weaned, the mother being returned to her breeding-pen and the control and X-rayed mice segregated and mated brother to sister. Wherever possible, an X-ray female was left with a control male. Normal females, which had produced at least one litter, were kept with the X-rayed males after a normal test period had elapsed sufficient to show that they were not already pregnant. These males had previously proved sterile with their own litter mates which had been exposed to X-rays.

Litters for exposure to X-rays were chosen when two or more litters of comparable size were born on the same day. From each of these litters a male and female were picked at random as controls. These control animals remained with the X-rayed animals during the first thirty days, except during the actual time of irradiation.

Every effort has, therefore, been made to keep all factors affecting the mice as nearly uniform as possible except the length of exposure to the Röntgen rays.

Comparative litter sizes were recorded on the basis of the number of young alive at two days of age. Larger litters in which more than one or two mice had died before the two-day limit, or litters which showed a mortality of more than one or two mice after the second day, were not used in computing

curves. This was done to avoid having weights of litters with a large number of mice of very low initial weight. These mice usually died before the second or third weighing, and since they were not available for computing the average rate of gain on later points up to thirty days would thus greatly influence the curve of the viable mice which remained. The average initial weights would be lowered by these individuals and thus the percentage

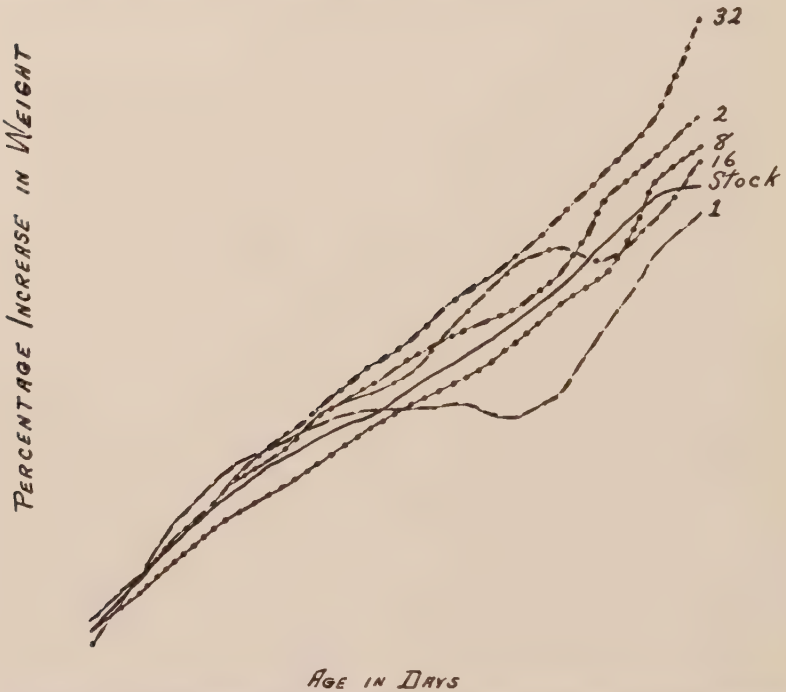

FIG. 28. Growth curves of mice (2d to 30th day) subjected to short exposures of X-rays. Numbers on right margin indicate length of each exposure in seconds

rate of gain for the viable mice markedly affected in an artificial manner. These precautions have reduced the available number of individuals, but at the same time have undoubtedly made for a more accurate curve of growth.

In the first series the length of exposure to the rays was va-

ried from 1 to 120 seconds. Five exposures were given. The first on the second day after birth and then on alternate days until the mice had received five exposures.

No change was noticed in the general appearance of the animals exposed to the series of five "1-, 2-, 8-, or 16-second" irradiations. Longer exposures of 32, 45, or 60 seconds, given in a series of five doses, produced white hairs in fairly constant pro-

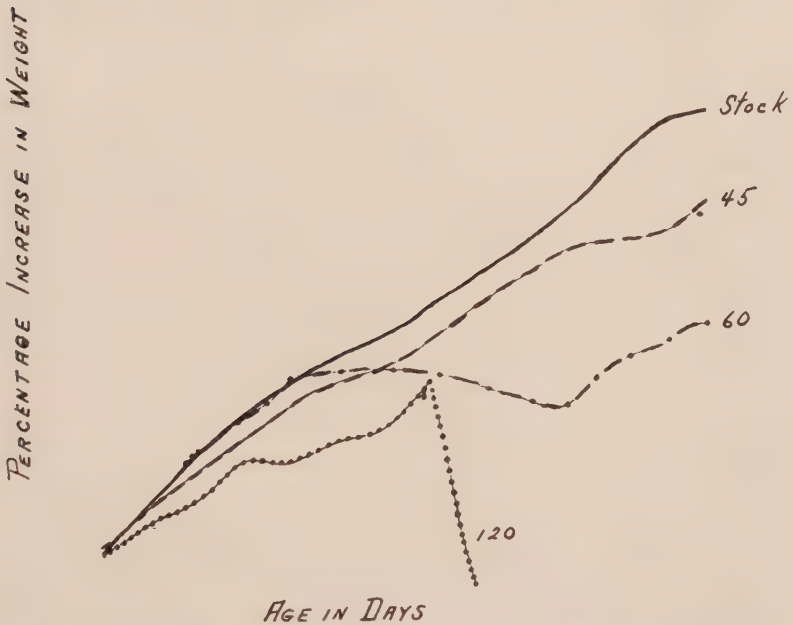

Fig. 29. Growth curves of mice (2d to 30th day) subjected to long exposures of X-rays. Numbers on right margin indicate length of each exposure in seconds

portion to the length of time of irradiation (a noticeable scattering of white hairs on the 32-second group, many more on the 45-second group, and a predominating white among the "60-second" individuals which survived).

The change in color is permanent. The production of white hairs does not appear to influence the quality of coat or cause baldness in any region.

In Figure 28 are shown the growth-curves of the animals X-rayed in a series of five doses of 1, 2, 8, 16 and 32 seconds, as compared with the normal control-curve. These curves were plotted as the average percentage increase in weight against the age in two-day intervals (average weight = average initial weight divided by the average initial weight and multiplied by one hundred). The unbroken line represents the control-curve while the broken lines represent the X-rayed groups as designated by numbers indicating seconds of exposure on the right hand margin.

In Figure 29 are shown the curves for animals which were exposed to a series of larger doses (45, 60, 120 seconds) as compared with the control-curve. The unbroken line again represents the control-curve and the broken lines the different groups of X-rayed animals. It will be noticed in this chart that the 120-second exposures proved lethal. This was found to be true also for the 60-second groups with the two individual exceptions before mentioned. In this curve the lethal action occurred at 24 days. From this point the curve represents the two exceptions only. One of these animals lived nearly four months, the other only a few days after the thirty-day period up to weaning.

Figure 30 gives the composite curve for the "1-, 2-, 8-, 16-, and 32-second" groups and the composite curve for the "45-, 60-, 120-second" groups compared with the control curve. It will be noticed that the groups exposed to the series of smaller doses follow closely the normal curve, while the animals exposed to the series of larger doses show a decided stunting effect of the treatment.

Mice exposed to the "one-second" series of irradiation have shown no apparent effect of the treatment. The animals have proved normally fertile. One very kinky-tailed female, No. 482, whose right eye never opened and which grew as a definite runt during the first thirty days, appeared in the F_1 generation (the first untreated generation after X-raying the parents). This female reproduced at 245 days of age a litter of 6 young by male No. 486, her brother. Two males from this litter of young were raised by a foster-mother and will if possible be back-crossed to their mother to determine whether she transmits these defects.

Female animals in all the other groups have proved sterile, but the males have reproduced apparently normal litters when mated with fertile stock females.

A functional disturbance in the nervous system occurs after exposure to the larger doses. The one female individual that survived the series of 60-second exposures, besides being stunted and showing many white hairs, exhibited a definite lack of nerv-

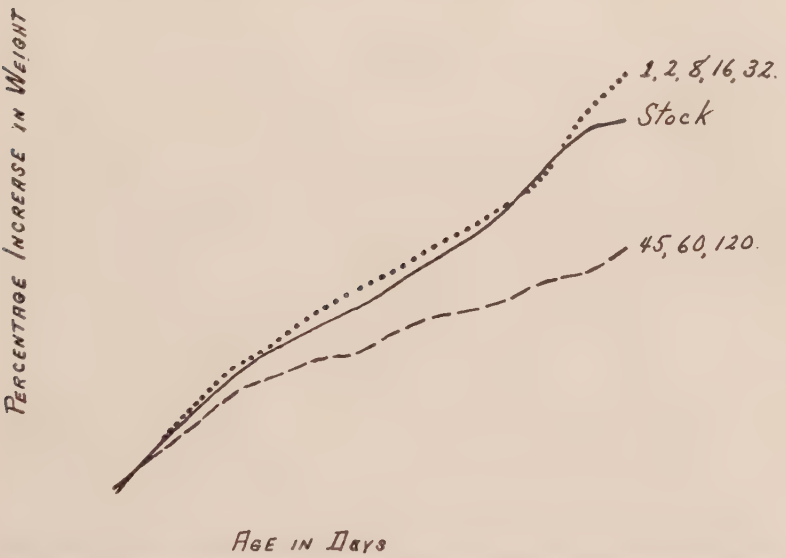

Fig. 30. Composite of curves shown in Figures 28 and 29, contrasting percentage increase in weight of mice exposed to short and to long doses of X-rays

ous control. Other animals exposed to a single dose comparable to the 60-second series showed this same defect. The mice in this condition are very excitable and when disturbed seem to lose all power of muscular coördination.

A number of single exposures have been given to check the effect of larger doses given at an early age. When they are treated at the age of two days with exposures of 1, 2, 3, 4, or 5 minutes, the results are similar to those of serial exposures of the same total intensity but spread over a longer time. The hair

color changes seem, however, to be more marked after the single exposures. The lethal dose is produced by a five-minute exposure. This corresponds to the five exposures of one minute each which usually proved to be lethal in the other groups. Among the mice exposed to one irradiation of from 2 to 4 minutes, a few have shown a marked functional disturbance in the nervous system and a decided stunting in growth.

We find in these preliminary exposures of young mice to Röntgen rays:

1. Production of white hair after a series of exposures equal to a 150 per cent human erythemal dose.
2. The amount of white hair produced varies in direct proportion to the length of time of exposure.
3. The change in color so produced is permanent, with no effect on quality of coat. There is no production of baldness.
4. There is a stunting in growth of mice exposed to a series of irradiations equal to 180 per cent of the human erythemal dose.
5. There is a lethal action of the X-rays after a series of exposures equal to 250 per cent of a human erythemal dose.
6. There is sterility in females after a series of exposures equal to one twelfth of a human erythemal dose.
7. There is fertility in the males after a series of exposures equal to 180 per cent of a human erythemal dose. The progeny of such animals when mated with stock animals are apparently normal.
8. Functional disturbance of the nervous system appears among individuals exposed to irradiations just below the lethal dose.

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FACTORS INVOLVED IN THE INCIDENCE OF SPONTANEOUS MAMMARY CANCER IN AN INBRED RACE OF MICE

WILLIAM S. MURRAY

IF THE life period of an individual is regarded from the viewpoint of rate of metabolic activity, it may be divided into four general periods:

1. An embryonic period in which growth is rapid, with very little breaking down of tissues.

2. The period from birth to maturity, during which the growth rate slows down gradually.

3. The period from maturity to middle age, in which metabolism is almost entirely taken up with maintaining the body in a state of repair.

4. The period of old age and senility, in which the process of repair is not able to keep pace with that of breaking down.

During the first three of these periods, or so long as there is physiological equilibrium of the metabolic processes, the individual may enjoy a state of health in which the various parts of the body grow or diminish at a rate which is beneficial to the well-being of the organism as a whole. When, however, this balance is disturbed by the inability of some organ, tissue or gland to fulfil its normal function, the ability of the individual to resist abnormal or detrimental growth is proportionately reduced.

One of the outstanding features of recent research in cancer has been the growing belief that neoplasms are the result of such unbalancing of metabolic activity and that they are not the result of disease, in the ordinary sense of the word.

Having settled upon this point, workers in the field go farther by agreeing that the appearance of cancer in an individual is

dependent upon one or both of two things: (1) An hereditary disposition toward the formation of neoplasms; (2) Some irritating substance working upon the organism. That is, any individual, if subjected to sufficient irritation, may possibly develop cancer, but individuals with the disposition toward cancer will contract it much more readily than those without this inclination. Also, individuals who inherit this tendency may develop tumor, even though the environmental stimulus is lacking.

It is our present purpose to demonstrate that the tendency toward the development of neoplasms of the mammary gland is an inherited characteristic in an inbred strain of mice, and to illustrate that this tendency is in some way aggravated by pregnancy and lactation.

As early as 1907, it was noticed by Haadland (1) and Tyzzer (2) that there seemed to be an hereditary tendency as regards the incidence of cancer in certain strains of mice.

Later, Lathrop and Loeb (3), in a series of publications which began in 1915 and ran through a number of years, expressed the conclusion, "that hereditary factors play a great part in the incidence of cancer among mice and that hereditary transmission is to a great extent responsible for the so-called endemic occurrence of cancer among animals." These two workers based their conclusions on the facts that they were able to show that strains with high tumor incidence transmitted this quality to their young and that strains of low tumor incidence transmitted a low tumor rate. The results of crosses between these two lines gave races which were of high, low and intermediate cancer incidence. These results suggest that possibly genetic factors were involved, since they are what might be expected where mass breeding rather than selective matings was employed.

With cancer in mice demonstrating in this way that it is inherited, attempts have been made by different workers to determine whether it behaves like a mendelian dominant or as a recessive. After several years of effort and controversy arising from conflicting evidence, opinion varies as to which of these is the true condition.

Beginning in 1913, Dr. Maud Slye (4) of the University of

Chicago has pubished a long list of papers in which she tabulates a great amount of data which she construes as showing that tumor is inherited as a mendelian recessive. The most convincing evidence which she offers is her claim that in her stocks a tumorous individual has never appeared in the first generation when mice of high tumor incidence were crossed with strains that were not tumorous. In support of her theory, she has published many pedigree charts, in which she attempts to demonstrate the homozygosity of her cancerous and non-cancerous stocks.

At first glance these are quite convincing, but if they are studied more thoroughly and compared with pedigree charts of the same strains published in previous papers, striking discrepancies and contradictions are found which show, in many instances, that only data favorable to the argument under discussion are used. Having found such discrepancies, one is inclined to question any conclusion derived from such data.

Dr. Clara Lynch (5), working at the Rockefeller Institute, has performed experiments which, while not as voluminous in data accumulated, show quite convincingly that adenoma of the breast in mice behaves as a mendelian dominant. Miss Lynch approached the problem in this manner:

1. If two individuals, one homozygous for cancer, the other homozygous for the absence of cancer, are mated, all the first filial generation will be heterozygous for cancer and will develop neoplasms, provided they live to cancerous age.

2. If individuals of this first filial generation are back-crossed to the dominant individual of the parent mating, the number of tumors expected should be more than will occur in the second hybrid generation. Also, if individuals of the first filial generation are back-crossed to the recessive parent, the percentage of tumorous individuals will be less than that which occurs among the second hybrid generation.

In her experiment Miss Lynch found this theory to be borne out by fact. Her evidence is not conclusive, however, because of the small numbers involved and because of the possibility that either one or the other of her parent stocks may have been heterozygous for tumor.

During the last few years, an attempt has been made in the laboratory at the University of Maine, and later continued at the University of Michigan, to build up by selective inbreeding a strain of mice which would be homozygous for cancer of the breast.

This study has been made slow and difficult by three characteristics of this type of tumor:

1. Because of the fact that cancer of the breast occurs only in the females, it is not possible to tell the genetic constitution of the males except by the incidence of cancer in their descendants.

2. Because of the fact that the age, in months, at which tumor occurs varies over a wide range of the life of the animal. This fact is illustrated by the curve of Figure 31 which shows the age of the individuals along the abscissa and the number of mice developing tumor along the ordinate. This curve demonstrates that in this inbred stock the tumor age varies between 4 and 14 months with a mode at 9 months, an arithmetic mean of 8.98 and a standard deviation from this mean of 2.005. This may be taken to mean that any mouse which does not live to be at least 7 months old need not be considered in calculating mendelian expectations; because there is no evidence which shows that at this age there is any differentiation in the mortality rate between cancerous and non-cancerous mice. This curve also shows that tumor will probably appear between the ages of 7 and 11 months, if it is going to appear, and that any individual which lives over 11 months, while probably non-tumorous, cannot be definitely so declared until death.

3. The third difficulty is encountered in the fact that it is only very seldom that a tumorous mouse has young after having given definite evidence of being cancerous. To obviate this an attempt has been made to keep at least one representative litter of each female in order that her line might be perpetuated should she develop tumor in her old age. In those mice in which a tumorous individual has given birth to young after she has definitely shown herself to be tumorous, the young have been saved and bred. It has thus been possible to build up several strains of very high cancer incidence.

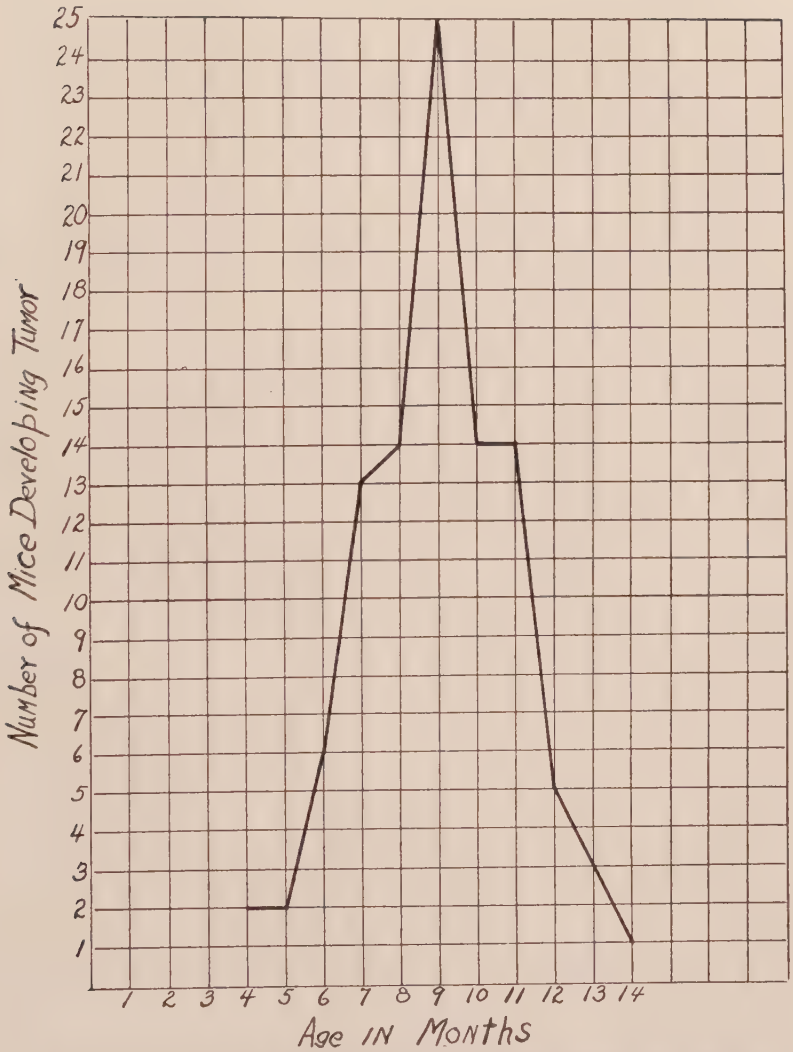

FIG. 31. Curve showing age at which dilute brown stock develops tumor (99 mice). Mode, 9; arithmetic mean, 8.98; standard deviation, 2.005

Line 1 (Figure 32), the best of these, dates back ten generations. During this time the mice were bred brother to sister except in two instances, when they were bred to closely related mice. Up to the eighth generation, tumor appears in but two instances, once in the third and once in the seventh generation. The siblings of several of the ancestors of these mice developed tumor, proving in this way that the parents of this line were tumorous, although they did not show it. This fact is especially striking in female No. 54847, for although she had five daughters all of which had tumor and a son which is evidently homozygous for tumor, she herself did not develop cancer.

In Line 2 (Fig. 33) is demonstrated a strain which has a high tumor rate. This pedigree also shows the difficulty of determining whether the genetic constitution transmitted is *Aa* or *AA* (where *A* = a dominant gene for cancer of the breast). Female No. 55663, tumorous, mated to her brother, had four daughters two of which developed tumor and two that did not. The tumorous daughters, mated to their brother (male No. 23111), had twelve daughters, of which seven developed tumor, three died before tumor age, and two died at ten and eleven months.

The two non-tumorous daughters, mated to the same male (No. 23111), had eight young, four of them tumorous and four non-tumorous. Three of the non-tumorous animals died before seven months and the fourth died at seven months.

Back-crossed to her son, female No. 55663 had ten daughters (Fig. 34), nine of which were tumorous and one that died before seven months.

From these data, it will be seen that the probable formula of

Female No. 55663 is *Aa* or *AA;*
Male No. 55659 is *Aa* or *AA;*
Male No. 23111 is *Aa* or *AA*.

Any of them may have been *AA* or *Aa*. They may all have been *AA* or any one of them may have been *Aa* while the other two were *AA*. The probability, however, is that female No. 55663 and male No. 23111 were *AA*, whatever male No. 55659 may have been.

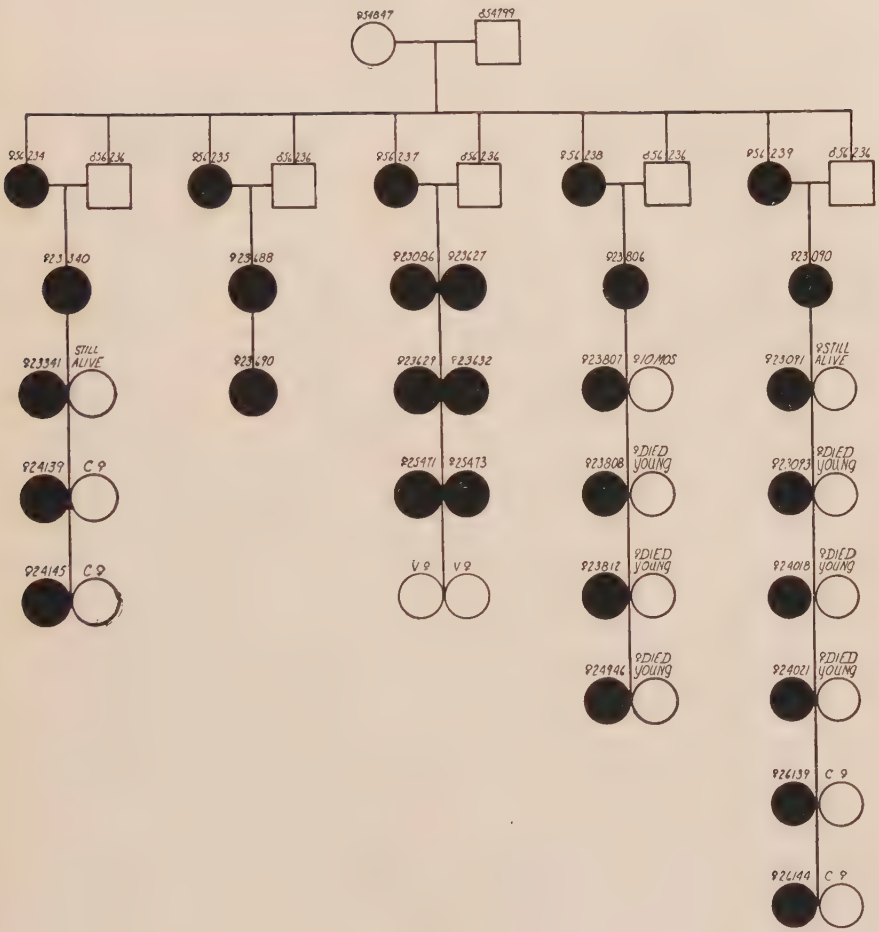

Fig. 32. Pedigree of Line No. 1

It will be seen from these pedigrees that cancer of the breast is clearly an inherited character which appears in the females of this stock between the ages of 4 and 14 months, usually between 7 and 11 months.

Since it appears among the females only, the question at once suggests itself: Does the variation in size and activity of the mammary glands themselves have any effect upon cancer incidence?

In order to test this theory, two hundred females of the cancerous stock were segregated at the age of one month and allowed to grow old under exactly the same conditions as the stock mice, with the exception that they have never been allowed to breed. At the present time (April, 1927), the youngest of these animals is eleven months of age. To date but one tumor has appeared in this stock (this individual developed tumor at ten and one-half months). While these mice are not over the extreme age (14 months) of cancer appearance, as shown on curve number one, they are beyond the mode of this curve and are now at the upper range of the standard of deviation of age at which tumor appears. Somewhere between the conception of the first litter and the appearance of tumor, the stimulus, external or internal, is given which initiates the neoplasmic growth. That this stimulus has begun to act at the date of birth of the first litter is demonstrated by the fact that the distribution of these two factors, computed for 97 cancerous females, shows a coefficient of correlation of $.339 \pm .060$. While this correlation is not great, it is nearly six times the probable error and may therefore have some significance.

If a distribution table is made which compares the number of young born to these same females and the age at which their tumors appeared, the coefficient of correlation is found to be $.377 \pm .058$. This is six times the probable error and therefore significant.

Of the young born in this stock, one third die before one month of age. We therefore computed the coefficient of correlation between the number of young suckled to weaning age (one month) and the age at which tumor developed. It is found to be

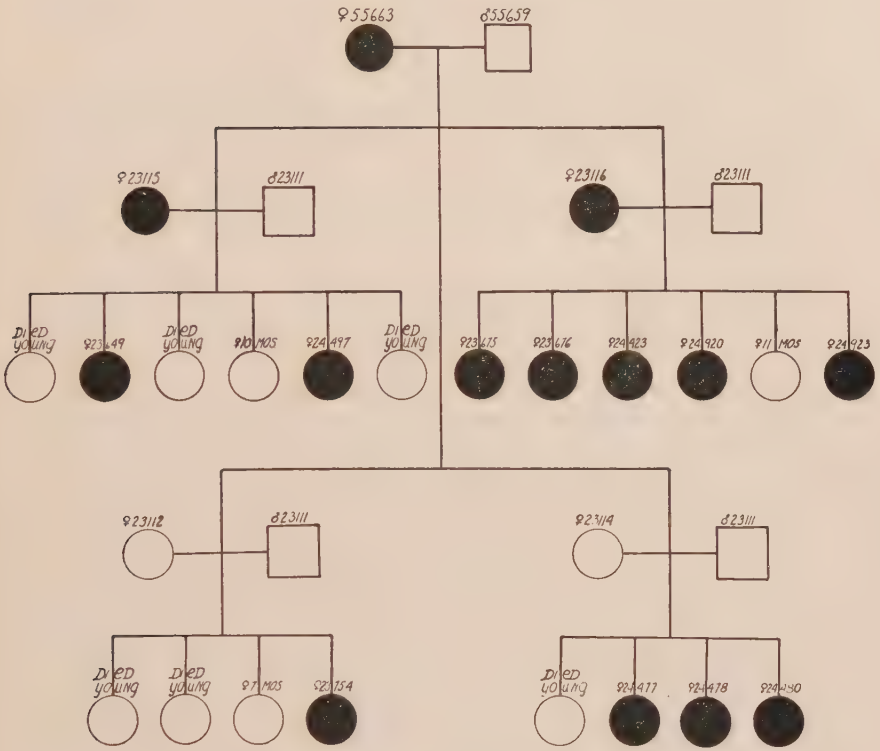

FIG. 33. Pedigree of Line No. 2

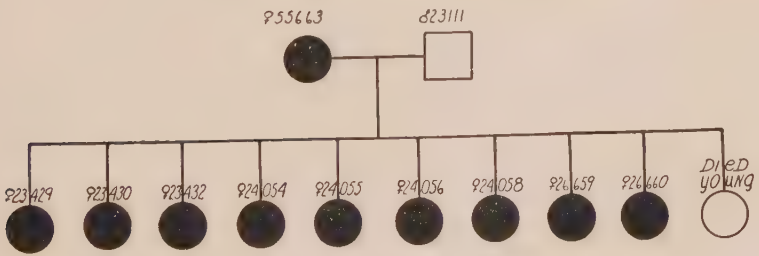

FIG. 34. Back-cross of Line No. 2.

.335 ± .060, or five times the probable error. Its significance is probably not great.

If one distributes, in the same way, the number of litters born and the age at which tumor appears, the coefficient of correlation is found to be .465 ± .053. This is nine times the probable error and therefore significant.

It may be concluded from these data that in this line of mice:

1. Cancer of the mammary gland is inherited, probably as a mendelian dominant.

2. The age at which cancer appears in virgin females is greater than the age at which it appears in females that have had young.

3. The morphological and physiological changes accompanying the bearing and nursing of young provide at least one of the stimuli for the starting of the neoplasmic growth.

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LIMNOLOGICAL INVESTIGATIONS ON NORTHERN MICHIGAN LAKES

I. PHYSICAL-CHEMICAL STUDIES ON DOUGLAS LAKE *

PAUL S. WELCH

INTRODUCTION

DATA contained herein represent investigations on Douglas Lake, Cheboygan County, Michigan, extending over fourteen summers, 1911–14 and 1917–26, pursued as a part of a general limnological survey which has been conducted by the writer and some of his graduate students on a number of lakes in the northern part of the Southern Peninsula of Michigan, particularly those near and in connection with the Cheboygan River Basin. This study was undertaken in order that some of the underlying factors which determine quality, quantity and distribution of life in Douglas Lake might be better understood; also that a foundation might be laid for an approach to the problem of the marked biological dissimilarity which exists among the various lakes in northern Michigan. It is the first intensive limnological study, by modern methods, of any of the five thousand or more (Scott, 1921, p. vii) Michigan lakes. The value of these data lies, in part, (1) in the fact that they extend over many summers, and, as will appear later, the possible inadequacy of a single season's results as an index of the expected sequence of events in lake environments is demonstrated; and (2) in the fact that the peculiar basin form presented unusual opportunities for a study of depression individuality.

A feature of unusual interest appears in the unique form of

* Contribution from the University of Michigan Biological Station and from the Zoölogical Laboratory, University of Michigan.

the Douglas Lake Basin. Seven distinct depressions (Fig. 35) occur in the main basin, each with an isolation depth contour of forty feet or less, and each manifesting, during the summer period, its own series of physical-chemical-biological phenomena. In other words, each depression, during the summer period, acts much as if it were an independent lake. This appears to be the first comparative study of independent depressions of a lake basin, particularly in the case of so large a number as exist in Douglas Lake, and under conditions which make them strictly comparable. Remoteness of Douglas Lake from the University of Michigan necessarily confined the work of each season to about three months in midsummer, usually June, July and August.

METHODS

Hydrographic Map. — At first no complete hydrographic map was available, but an outline map of the lake and sounding records in a few restricted areas were provided by Professor C. T. Johnston, director of the University of Michigan Surveying Camp. This explains the absence of work on some of the depressions during the earlier years. Later, 1921, a complete map, based upon more than four thousand soundings was generously supplied by Professors Johnston and T. J. Mitchell.

Temperature Records. — 1. Negretti and Zambra reversing thermometers of the modern deep-sea type, mounted in a Tanner case modified essentially as described by Juday (1916, pp. 588–590), were consistently used in this work. Each instrument had been tested at a pressure of three tons and all corrections were available. These thermometers were used as the standard in the correction of other temperature-recording instruments.

2. A thermophone of the modern type was employed during certain seasons. It was frequently checked against the reversing thermometers to insure that it was in proper condition.

3. Six's Combination Thermometers, designated as "Tycos" and manufactured by the Taylor Instrument Co., Rochester, New York, were used occasionally. These instruments have certain inherent limitations, but when properly used and corrected were often convenient.

FIG. 35. Map of Douglas Lake, indicating positions of the seven principal depressions (*modified from map by Department of Geodesy and Surveying, University of Michigan*). Isolation contours only are shown for each depression and are slightly diagrammatic. The numeral on each contour indicates its depth. Maximum depths are expressed by the numerals within the depression contours.

Other Instruments. — Shore lines and submerged contour lines were measured by a standard map measurer. All areas, surface or submerged, were determined by means of a polar planimeter.

Sampling. — At first, water samples at various depths were taken with a plankton pump and hose properly protected against leakage, and some use was made of a collecting bottle modeled after the one described by Whipple (1914, pp. 26–27, Fig. 10), but both of these were soon abandoned in favor of a modified Kemmerer Water Bottle, described and illustrated by Birge (1922, pp. 547–549; Pl. XL, Figs. 6–7), which for most purposes was found to be superior to all others. Limited use was made of Theiler's Water and Plankton Sampler. Samples were collected in 260 c. c. glass stopper bottles equipped with water-proof tags and every care was taken to avoid error in sampling by strict observance of proper collection, bottling, stoppering, recording and storage of the samples. These precautions are too well known to require description here.

Analyses. — Previous to 1919 all determinations of dissolved oxygen were made by the Winkler method as outlined by Birge and Juday (1911, pp. 13–21). Since that date the method described in *Standard Methods of Water Analysis* (third, fourth, fifth and sixth editions, 1917, 1920, 1923, 1925) was employed. Parallel tests showed that for Douglas Lake waters the two methods yielded almost identical results except in the samples taken from the lowermost one-half foot level, where the water contains a larger amount of organic matter. Since it was seldom necessary or feasible to secure and analyze samples from the level immediately above the bottom muck beds, the slight defect of the older method was of no significance.

Aside from an early and limited use of the Seyler method (Birge and Juday, 1911, pp. 21–24), all determinations of carbon dioxide, alkalinity, and oxygen consumed were made by methods described in *Standard Methods of Water Analysis.*

Hydrogen ion concentration. — Determination of hydrogen ion concentration by the colorimetric method became a part of the regular routine in 1920. During that season a phenol red color-

imeter made by the Hynson, Westcott and Dunning Pharmaceutical Laboratory, Baltimore, Maryland, having a range of pH 6.8–8.6 and intervals of pH 0.2, was used, but it was soon discovered that for certain other adjacent natural waters a much greater range is required. Hence, for the work of the seasons 1921, 1922 and 1923 colorimeters made from standard buffer and indicator tablets secured from the Pyrolectric Instrument Company, Trenton, New Jersey, range pH 2.0–9.8 and intervals of pH 0.2, were used. The indicators were thymol blue (acid range), 2.0–2.8; brom phenol blue, 3.0–4.6; methyl red, 4.4–5.8; brom cresol purple, 5.4–7.0; brom thymol blue, 6.0 7.6; phenol red, 6.6–8.4; and thymol blue (alkaline range), 8.2–9.8. The solutions were hermetically sealed in alkali-free glass tubes. Colorimeters used during the seasons of 1921, 1922 and 1923 were constructed and corrected by Dr. Minna E. Jewell.

For the seasons of 1924–26 colorimeters prepared by the La-Motte Chemical Products Company, Baltimore, Maryland, were provided, the indicators and pH values being as follows: meta-cresol purple, 1.2–2.8 (thymol blue, acid range, in 1924); brom phenol blue, 3.0–4.6; brom cresol green, 4.0–5.4; brom cresol purple, 5.4–7.0; phenol red, 6.6–8.2; and thymol blue (alkaline range), 8.2–9.8. Intervals, pH 0.2.

Colorimeters were made or secured new at the beginning of each season and checked against duplicate tubes, against identical samples within overlapping values of different indicators, and against Clark's color chart (1920). They were watched constantly for evidence of color change, and when such change occurred either correction was made or a new tube was substituted. Duplicate colorimeters were always provided.

Time of Analyses. — The desirability of analysis at the moment of sampling was recognized, and by the use of specially designed portable chemical kits it was possible to make determinations of dissolved oxygen (final titration was made in the laboratory within six hours), carbon dioxide, alkalinity and hydrogen ion concentration in the boats, thus eliminating all possibility of error due to storage of samples. This method afforded the added advantage of making it possible to repeat at

once determinations which for any reason seemed doubtful or unusual. Duplicate analyses were often made merely for confirmation.

ACKNOWLEDGMENTS

The writer acknowledges his indebtedness to Professors C. T. Johnston and T. J. Mitchell of the Department of Geodesy and Surveying, University of Michigan, for the use of the hydrographic map of Douglas Lake; to Professors R. H. Holman and Ernest Reed for an unpublished series of vertical temperature records from Douglas Lake, summer of 1917; to Professor Frank Smith for some unpublished, vertical temperature records taken at irregular intervals during 1911–14; to Mr. F. E. Eggleton for the use of certain vertical physical-chemical determinations made during the summers of 1923 and 1926; and to Dr. Minna E. Jewell for general assistance in making lake records. Finally, to various other persons who from time to time gave assistance in this work the writer acknowledges indebtedness.

MORPHOMETRY

Several papers published from the Biological Station have incidentally included brief descriptions of Douglas Lake, as for example, that of Reighard (1915, pp. 219–221). Scott (1921, pp. 106–117) presented a detailed discussion of the physiography and geological history of Douglas Lake. The meager morphometric data in each of these papers — all then available to the authors — will receive herein a certain amount of correction.

All morphometric data are based upon a large hydrographic map made by the Department of Geodesy and Surveying, on a scale of 1 inch to 400 feet, and containing more than 4000 sounding records. The author of this paper is, however, entirely responsible for the construction of the submerged contour lines of the copy used, for the computation of all shore lines, surfaces and volumes, and all other calculations.

Maximum length	3.8 miles
Maximum breadth	2.27 miles
Mean breadth	1.53 miles
Direction of main axis	northwest and southeast
Area	5.83 sq. miles
Elevation	710 ft. (standard low water datum)
Maximum depth	89 feet (standard low water datum)
Mean depth [1]	17.9 feet
Length of shore line (inclusive of island)	15.61 miles
Length of shore line (exclusive of island)	14.07 miles
Shore development (including island)	1.85
Shore development (excluding island)	1.67
Mean slope of bottom [1]	2.6%
Number of soundings	4145
Volume	2,919,530,400 cu. feet
Volume development	0.604

[1] Computed according to the formulae used by Birge and Juday (1914, p. 122).

TABLE 1

AREAS AT VARIOUS LEVELS*

Depth (feet)	0	10	20	30	40	50	60	70	80
Area (sq. miles)	5.83	2.81	1.85	1.37	0.74	0.48	0.29	0.11	0.03
Percentage of surface	100	48.2	31.8	23.4	12.7	8.1	5.1	1.9	0.5

TABLE 2

VOLUMES AT VARIOUS LEVELS*

Stratum (feet)	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–89
Percentage of total vol.	40.4	22.2	15.3	9.9	5.7	3.6	1.9	0.6	0.1
Underlying volume in percentage of total	59.6	37.3	22.0	12.0	6.3	2.6	0.7	0.1	0.0

* Values represent a total for all depressions.

DEPRESSIONS

Douglas Lake is unique in the possession of seven distinct depressions (Fig. 35) within its basin, the maximum depth of each exceeding 50 feet. An eighth depression of considerable extent but having a maximum depth of only 44 feet occurs opposite Pine Point, but its relative shallowness and its exposed position render it of less significance, since thermal stratification usually occurs only in temporary form and often is totally absent. It is, therefore, left out of account in the following considerations.

TABLE 3

DEPRESSIONS

Name	Camp Davis	Sedge Point	Grapevine Point	Stony Point	Roberts Point	Fairy Island	Maple Point
Maximum depth (feet)	79	79	81	59	72	89	55
Area at isolation level (sq. miles)...	0.142	0.066	0.142	0.025	0.138	0.253	0.025
Isolation level (ten-foot contour).....	30	40	30	40	20	40	40

There seems to be no serious reason for attempting to work out isolation levels closer than the nearest safe 10-foot contour. Actually, the exact isolation level in each depression is nearer the surface than the figures in Table 3 indicate, but seasonal changes in surface elevation of from two to three feet would convert any closely selected level into a variable, within that range. In at least two instances, the irregularities of the bottom intervening between two depressions (between Maple Point and Fairy Island depressions, and between Grapevine Point and Sedge Point depressions) are such that, in spite of the frequency of the sounding records, the location of the *closest* isolation con-

tour is a matter of judgment. The writer has preferred to use the unquestionable ten-foot contour in each case.

THERMAL RELATIONS

Stratification dates. — With rare exceptions to be mentioned later, typical thermal stratification occurred during the summer season. However, variation in the dates of stratification must be expressed for the different depressions, since each tends to act independently. The major depressions usually show distinct stratification previous to late June, although it has not been possible for the writer to be at Douglas Lake early enough to witness the overturn and subsequent beginnings of stratification, thus ascertaining definitely the exact dates of its initiation. Delayed stratification appears in the records, as for example, in 1917 on July 4 the Camp Davis depression was permanently stratified and the form and position of the thermocline indicated a considerable previous existence, but in the Fairy Island depression the thermocline was not formed until between July 12 and July 18, and in the Sedge Point depression definite stratification first appeared between July 24 and July 31. Also in 1922, the Camp Davis depression showed permanent stratification on June 7, accompanied by some evidence that it was of recent origin, but the Stony Point depression did not develop a thermocline until between July 29 and August 5. During the summer of 1918 the Camp Davis depression showed a bottom temperature of above 14 degrees Centigrade and up to July 24 showed no indications of stratification, while the Fairy Island depression showed a bottom temperature of above 15 degrees Centigrade and manifested no indications of stratification up to August 16. Circumstances prevented examinations later than the dates mentioned above, but it is likely that no permanent stratification occurred. This condition was apparently due to a long series of severe spring and summer storms so distributed and of sufficient severity to prevent the normal stratification. Only two other depressions were known in 1918 and they were not studied.

Tucker (1913) published a series of vertical temperature

records taken during July and August, 1912, mostly from the Camp Davis depression which is erroneously referred to as the deepest part of the lake.

The peculiarities of the 1926 season will appear in the following section.

Depression Differences in Stratification. — As the records accumulated, consistent differences in the extent and position of the thermocline appeared in the six major depressions (Fig. 35) on the same date, ultimately indicating that each depression acts independently of the others. The following selected data (Table 4) will indicate the nature of these differences. A more extended comparison of thermocline positions shows essentially the same results. Thermocline positions are indicated in terms of feet.

TABLE 4

Date 1922	Depressions					
	Camp Davis	Sedge Point	Grapevine Point	Stony Point	Roberts Point	Fairy Island
July 29	45–55		50–65	Absent		35–55
Aug. 5	40–60	45–60	50–65	20–25	35–55	50–55
Aug. 12	40–60	45–60	50–65	45–50	35–55	40–55
Aug. 16	40–55		45–65			35–55

Since it necessarily followed, in the usual procedure, that the temperatures in the various depressions were not determined simultaneously, series of records were made on a calm day, August 9, 1923, by three observers from boats anchored over the Camp Davis, Sedge Point, and Fairy Island depressions. Vertical temperature records were made simultaneously in the three depressions once every hour from 9 o'clock A.M. to 5 P.M., inclusive, and at depth intervals of two and one-half feet to bottom. The results showed the thermocline positions to be different and very constant, and while the dissimilarity of strati-

fication in the three selected depressions was not as great as in some other seasons, their individual constancy was demonstrated.

These evidences and others, including those from the numerous chemical analyses, have indicated clearly that when, during the summer, the lower portions of the thermocline sink below the isolation levels of the various depressions, each depression acts as an independent unit and frequently manifests distinct contrasts with adjacent depressions. In addition, it may happen that the depressions act independently with respect to the presence or absence of stratification. Ordinarily, all six deeper depressions stratify thermally; at very rare intervals, as in 1918 already referred to, stratification is absent; but in 1926 a striking individuality in depression behavior occurred in the form of a mixed condition in which one depression was thermally stratified as usual; three depressions showed complete absence of stratification throughout the season; and two depressions, stratified at the beginning of the season, later lost the stratification at approximately midsummer. Table 5 presents some of the essential details of this unique series. Correspondingly peculiar chemical conditions appeared in the various depressions. The individual, independent action of the various deeper depressions was thus strikingly confirmed.[3]

[3] Since this paper was presented for publication results for the season of 1927 have been secured and further confirmation of depression individuality appears. Three depressions were thermally stratified throughout the season: Camp Davis, bottom temperatures 10.7–11; Fairy Island, bottom temperatures 12.6–12.8; Roberts Point, bottom temperatures 12.2–13.0. Two depressions showed no thermal stratification at any time: Stony Point, bottom temperatures 16.0–19.0; Grapevine Point, bottom temperatures 15.2–17.8. One depression showed only a temporary thermal stratification early in the season: Sedge Point, bottom temperatures 12.9–14.3.

TABLE 5

THERMAL-CHEMICAL CONDITIONS IN THE DEPRESSIONS OF DOUGLAS LAKE, SUMMER OF 1926

Thermocline position in feet; Temperatures in degrees centigrade; t. s. = thermal stratification; c. s. = chemical stratification; c. gr. = gradual change in chemical conditions from surface to bottom; unf. = chemical conditions approximately uniform from surface to bottom.

Camp Davis Depression Depth 79 ft.			Sedge Point Depression Depth 79 ft.			Grapevine Point Depression Depth 81 ft.		
Thermocline	Bottom Temp.	Chemical Conditions	Thermocline	Bottom Temp.	Chemical Conditions	Thermocline	Bottom Temp.	Chemical Conditions
7/13 = 49–65	6.9	c. s.	7/15 = no t. s.	16.3	c. gr.	7/14 = no t. s.	18.3	unf.
7/21 = 45–55	8.4	c. s.	7/26 = no t. s.	17.2	c. gr.	7/24 = no t. s.	18.3	c. gr.
8/9 = 49–62	7.6	c. s.	8/5 = no t. s.	17.2	c. gr.	8/6 = no t. s.	17.8	c. gr.
8/26 = 49–62	8.2	c. s.	8/27 = no t. s.	16.9	c. gr.	8/23 = no t. s.	18.1	unf.

Stony Point Depression Depth 59 ft.			Roberts Point Depression Depth 72 ft.			Fairy Island Depression Depth 89 ft.		
Thermocline	Bottom Temp.	Chemical Conditions	Thermocline	Bottom Temp.	Chemical Conditions	Thermocline	Bottom Temp.	Chemical Conditions
7/17 = no t. s.	18	unf.				7/16 = 59–78	9.4	c. s.
			7/23 = 36–39	14.4	c. gr.	7/28 = 62–72	12	c. s.
8/16 = no t. s.	18	c. gr.	8/3 = no t. s.	15.3	c. s.	8/6 = no t. s.	11.3	c. s.
8/27 = no t. s.	18	c. gr.	8/16 = no t. s.	14	c. s.			

TABLE 6

BOTTOM TEMPERATURES

In degrees Centigrade

Depressions	1911	1912	1913	1914	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	Extremes
Camp Davis	8.3	10	9.4	6.4	8.3	14.2	8.6	7.8	9.2	6.2	8.4	11	10.6	6.9	6.2–14.2
Sedge Point					10.7				10	9.9	10		16	16.3	9.9–16.3
Grapevine Point				15.8				10	11.1	9.5	9.4		16.8	18.3	9.5–18.3
Stony Point										12.1			17.2	18	12.1–18
Roberts Point										9.6			11.2	14.4	9.6–14.4
Fairy Island				9.5	10.8	15.3	10.3	9.3	10.7	8.5	8.9	10.9	11.4	9.4	8.5–15.3

Bottom Temperatures. — Variations appear in the bottom temperature of a depression. The second column of Table 5 shows the character of these differences, as does also Table 6, which includes the bottom temperatures as they occurred at or near the middle of July of each year. Considering the fact that five depressions are 72 feet or more in depth, the differences during the various summers are rather striking. The highest temperatures are coincident with absence of thermal stratification, but even during seasons when stratification was established in all six major depressions, as for example in 1922, an unexpected variation occurred. Of special interest are the 1926 temperatures for the Grapevine Point depression (depth, 81 feet) and the Stony Point depression (depth, 59 feet) of 18.3 and 18.0 degrees Centigrade, respectively. Often these bottom temperatures were within 1 to 2 degrees of the surface water temperatures, and obviously thermal stratification was impossible even had the season been one of unusual calm. For a given season the

most protected depression, Camp Davis depression, shows (one exception in 1924) a bottom temperature lower than all the others, although its depth is equal to or less than three of the more exposed ones.

Increase in Bottom Temperatures. — Another feature deserving notice is an occasional variation during a given season within the same depression, which takes the form of a gradual but definite rise in the bottom temperature. The character of these increases is indicated in the second column of Table 7. A certain limited random variation occurs in bottom temperature records even after the proper corrections are made, but quite apart from these there appears at times a progressive rise in temperature, which, repeated again and again in the records in the same fashion, seems too definite to be due to error. The sequence, when it occurs, is always from a lower to a higher temperature, and the increment seems always to be of a gradual nature. In some of the records, the total increase for the season is less than one degree, an amount which might be regarded as of doubtful significance were it not for the fact that the nature of the increase, the occurrence of larger differences (up to 4.6 degrees) in other depressions, and the repeated occurrence of the same phenomenon give the smaller values more than accidental meaning. Furthermore, the large number of records made for some seasons and the frequent use of the Negretti and Zambra Deep-Sea Reversing Thermometer, graduated in 0.2 of a degree and safely readable to 0.1 of a degree by an experienced observer, give added significance to these records. In 1913, 1914 and 1920 the Camp Davis depression showed the following temperature increases: 9.2–10.3; 6.1–7.3; and 7.9–8.5. In 1922 five of the depressions showed the following increases: Camp Davis, 6.4–7.5; Grapevine Point, 9.4–9.9; Stony Point, 12.1–16.7; Roberts Point, 9.6–9.8; and Fairy Island, 7.9–8.5. In 1926, the following records occur: Camp Davis, 6.8–8.2; Sedge Point, 16.3–16.9; and Fairy Island, 9.4–11.3. A few other similar records appear among the accumulated data.

It should be noted, however, that this increase of bottom temperature with seasonal advance is not a regular performance,

since it appears to be absent at times. Inspection of Table 7 will yield instances. Occasionally, as in 1922 and 1926, certain depressions show the temperature increase and others do not; likewise, it appears that a given depression may manifest the temperature increase during one season and fail to do so another season. When present, the phenomenon appears to be independent of the presence or absence of thermal stratification. It is vaguely possible that in some of the apparent cases of absence of temperature increase, an increase might have been detected had the period of observation been more extended, although it would seem that some indication of temperature increment should appear within two months, particularly since that interval was ample in other seasons.

No explanation of this bottom temperature increase is attempted at this time; likewise none is offered for the random variations which appear in some of the records. Such variations were recognized at the time of taking the records and repeated readings were often taken for the sake of confirmation. Various possible causes of both phenomena have been considered by the writer and his co-workers, but none have yielded any positive results as yet. Jewell (1927) presents circumstantial evidence of the entrance of underground water below the thermocline in Douglas Lake. The actual entry of such water remains to be demonstrated, although it seems possible. The effect of such a phenomenon on the seasonal changes in bottom temperature cannot be discussed at present with any certainty.

General Features of Stratification. — The general thermal relations involved in stratification manifested in lakes of the type represented in Douglas Lake are too well known to justify discussion here. Table 7 indicates the essential details and includes series of records selected from the larger mass of available data. Because of their volume, the publication of all records was impossible. Therefore, the author has attempted to select a few significant ones for each season.

The varying extent in time of the records on the various depressions reflects the history of hydrographic knowledge of Douglas Lake, the series being much longer for the Camp Davis

and the Fairy Island depressions because they were the first ones known. Other depressions were investigated in the order of their discovery.

The form and seasonal history of the thermocline in the various depressions were found to be typical, originating early in the season as a high, thick zone which gradually diminished in thickness and descended in position as the season progressed, accompanied by corresponding reduction in the volume of the hypolimnion. Secondary thermocline formation was of occasional occurrence in the deeper depressions, although dependent upon weather conditions and never present for more than a few hours.

All vertical temperature records by the author and his assistants were made uniformly at intervals of five feet, and often at two and one-half feet through the thermocline region.

In all cases of stratification, thermocline limits have been determined according to the usual rule of temperature difference (Birge, 1904, p. 6) of 1 degree Centigrade per meter or 0.304 degree Centigrade per foot.

CHEMICAL RELATIONS

General

Chemical work was begun in 1918, interrupted in 1919, resumed in 1920 and continued during each season thereafter, making a total period of eight summers. During the first summer the analyses included dissolved oxygen, carbonates, bicarbonates and free carbon dioxide. During all succeeding seasons hydrogen ion concentration determinations were a regular part of the procedure and occasional oxygen consumed tests were made. All series of vertical samples were accompanied simultaneously by corresponding temperature records. Each series consisted of samples taken from the surface to bottom at ten-foot intervals, with occasional smaller intervals as circumstances demanded. As stated elsewhere, duplicate samples were often analyzed where confirmation seemed desirable.

During the eight summers about one hundred and fifty series of vertical water samples were analyzed. In addition, approxi-

mately one hundred surface water samples from various parts of the lake were determined. Publication of this mass of data, even in summarized form, is impossible. Therefore only general results and interpretations can be presented here.

Previous work. — The first chemical work on Douglas Lake was done by Tucker (1913, pp. 121–128) during the summer of 1912. The "greater number" of his samples were taken in the Camp Davis depression, which is erroneously referred to as the deepest part of the lake, and since it is implied that some of the records were taken in other parts of the lake which are not specified either by position or in the tables, it is difficult to make any use of his results, since each depression has its own individual seasonal history.

Dissolved Oxygen History

Each of the seven depressions in the Douglas Lake Basin regularly reduce the dissolved oxygen in the bottom as the season progresses, and ordinarily a considerable volume of the lowermost water ultimately becomes entirely devoid of it. This phenomenon normally tends to occur, at least to some extent, even in the absence of thermal stratification, although there is always the likelihood that because of the higher bottom temperatures at such times periodic circulation will occur and thus oxygenate the bottom water. Typically, oxygen exhaustion characterizes the whole of the hypolimnion after the early part of July, although the actual date may vary somewhat as indicated in Table 8, and continues uninterrupted until the approach of the fall overturn.

It seems probable that the decomposition of accumulated organic matter at the bottom plays an important rôle in the reduction of the dissolved oxygen and possibly is the sole cause. All the major depressions contain, at the bottom, large quantities of more or less finely divided muck, the uppermost layer of which is in partial suspension in the water. Such materials undergo decomposition, even under conditions of low temperature, with the well-known effect on the dissolved oxygen of the superimposed water. Jewell (1927) discusses the possibility of a subterranean

water-supply in Douglas Lake and points out that, if it should enter the basin at low levels, it would contribute to the volume of oxygenless water, since underground water is characteristically low in dissolved oxygen.

The epilimnion is, of course, a region where oxygen is maintained at a high quantity throughout the season. The apparently small quantities during the early part of the season of 1921 were the result of unprecedented high lake surface temperatures (Hubbs, 1923, p. 209, Fig. 7). The permanently established thermocline becomes the region of rapidly diminishing oxygen, often falling from amounts approximating saturation at the upper limit to total absence at the lower limit.

Alkalinity

In accordance with the standard practice, two initial indicators were used, phenolphthalein, and methyl orange.

Phenolphthalein. — The deeper waters invariably gave no reaction to this indicator, while the upper waters showed so little that the quantity and the normal error of titration almost made it negligible. Often a drop or two of the acid would completely pass the end point. Frequently there was a close correlation between the upper limit of the thermocline and the lowest limit of color reaction to this indicator and during certain seasons the correlation was quite constant for the various depressions Other records, however, showed the color reaction fading out well above the thermocline. Usually, the decrease from the surface to point of disappearance was gradual. With the tendency to follow the thermocline, the lowest limit of reaction usually grew increasingly deeper with the progress of the season. Titration quantities never exceeded 1.0 c. c. at the surface and were almost invariably much less. So slight were these quantities that it scarcely seemed worth while to include them in Table 8.

Methyl Orange Alkalinity. — The methyl orange alkalinity in parts per million of calcium carbonate is indicated in the corresponding column in Table 8. From these results and the information concerning the phenolphthalein alkalinity given above, the calculations for carbonate, bicarbonate, and fixed and half-

bound carbon dioxide can be made by well-known methods. It will be readily seen that the quantities of fixed carbon dioxide are such that in the classification of lakes on this basis used by Birge and Juday (1911, pp. 75–76), Douglas Lake would barely qualify as a hard-water lake ("third class"), or perhaps be looked upon as an intergrade between the medium class and the hard-water class.

Hydrogen ion Concentration

An inspection of the pH columns in Table 8 will yield the principal features of the pH history and extensive discussion seems unnecessary. It will be noted that occasionally five of the depressions develop acid conditions late in the season in the lowermost water which may prevail throughout the whole hypolimnion, although never exceeding 6.7. Typically, the epilimnion shows a small, gradual fall in pH value, while the thermocline is a region of conspicuous diminution. Under conditions of absence of thermal stratification, bottom waters may approximate the pH of the surface early in the season, but unless periodic circulation intervenes, the usual fall will occur.

Physical-chemical Correlations

1. *Thermal Stratification Conditions.* — With the onset of permanent thermal stratification there soon appears a progression towards a corresponding distribution of the chemical features, leading to a chemical stratification in which the correlations are very close for all the factors determined except the methyl orange alkalinity. The thermocline becomes (1) the region of rapid fall of dissolved oxygen content from generous quantities at the upper limit to zero at the lower limit; (2) the region of rapid change in pH; (3) the upper limit of free carbon dioxide; and (4) the lowest limit of phenolphthalein alkalinity. The pH 8.0 limit comes to correspond very closely with the upper limit of the thermocline and the pH 7.0 limit ultimately rises to the lower limit of the thermocline and continues there for the remainder of the season. The usual fall in level and the reduction of thickness of the thermocline with the progress of the season are accompanied

by corresponding changes in the chemical features, so that the correlations continue until the fall overturn. So closely do these phenomena correspond in their distribution that it is possible to predict, ordinarily, the chemical distribution from a thermal stratification record. These statements hold for each of the six major depressions.

2. *Absence of Permanent Thermal Stratification.* — In the absence of thermal stratification, chemical stratification does not appear. Ultimately the processes going on in the bottom of a depression lead to a *gradual* reduction of the dissolved oxygen and a *gradual* change in the pH values in the direction of neutrality, but a vertical series of samples show an approximation to a gradient rather than a stratification. Since bottom temperatures are likely to be high under these conditions, there is always the possibility, occasionally realized, of wind action circulating the whole depression and restoring uniform chemical conditions from surface to bottom.

Productive Volume

The complete disappearance of dissolved oxygen from the hypolimnion converts that volume of the lake into a veritable biological desert. Several species of animals can successfully endure the anaerobic conditions at the bottom, but the superimposed deoxygenated water contains no forms which can be regarded as normal inhabitants of that region. Certain species occur in abundance near the upper edge of the oxygenless zone where the dissolved oxygen content is quite low, but are ruled out when the oxygen content is further reduced. Since thermal stratification for the majority of the depressions is the usual condition, it follows that for about three months at least there is developed a non-productive volume which plays no part in the biological productivity of the lake. The remainder of the lake, the epilimnion and the thermocline, constitutes the productive volume. Since much of the volume of Douglas Lake lies above the isolation levels of the bottom depressions, and since the mean depth is only 17.9 feet, it is evident that the non-productive volume must be relatively small, frequently less than 10

per cent. Since the hypolimnion may vary in each depression and since, at times, certain depressions do not develop a hypolimnion at all, it would be difficult to compute a satisfactory value for the non-productive volume, even from the large number of data at hand. Rarely, a season such as 1918 occurs in which the whole lake fails to stratify; then the entire volume becomes potentially productive. When thermal stratification predominates, it appears that the productive volume may reach, and even exceed, 90 per cent of the total volume.

SUMMARY

1. Results of a long-continued physical-chemical study of Douglas Lake, Michigan, are presented and constitute the first intensive limnological study, by modern methods, of any of the numerous inland Michigan lakes.

2. Morphometric data are presented in considerable completeness. This lake is unique in the presence of seven distinct, independent depressions within the main basin, each with an isolation depth contour of 40 feet or less, and presents unusual opportunities for a study of depression individuality.

3. Ordinarily, thermal stratification occurs during the summer in all six major depressions, but each acts as an independent unit with respect to (1) date of stratification; (2) position, form, and thickness of the thermocline on a given date; (3) seasonal history of stratification, when established; (4) presence or absence of stratification; and (5) permanency of stratification when established.

4. Bottom temperatures in the six major depressions may vary widely (1) in the same depression, from season to season, and (2) in the different depressions on the same date, notwithstanding similarity in depth, size and position. During the rare absences of thermal stratification, the bottom temperature, ordinarily below 10 degrees Centigrade, may be within one or two degrees of surface water temperature, even at more than eighty-foot depth.

5. Bottom temperatures in a given depression not infrequently show gradual increases as the season advances. These

gains may vary from a fraction of a degree to 4.6 degrees Centigrade. They may be absent in certain depressions, present in others; they may occur in a depression during one season and be absent during another. Definite progressive changes, when present, were always increases, never decreases.

6. Analyses of about one hundred and fifty series of vertical water samples, distributed over a period of eight summers, are summarized and discussed. These data show, among other things, the following features:

(*a*) Each depression reduces the dissolved oxygen in the bottom, usually to zero, and ordinarily a considerable volume of the lowermost water becomes oxygenless. While this phenomenon is most marked during thermal stratification, it tends to occur in the absence of thermal stratification, although there is the likelihood of a reoxygenation by a circulation of the entire volume.

(*b*) Phenolphthalein alkalinity is confined to the upper waters and is practically negligible. Methyl orange alkalinity is indicated in Table 8. The quantities of fixed carbon dioxide indicate that Douglas Lake is approximately an intergrade between the "medium" and the "hard-water" classes of lakes.

(*c*) Hydrogen ion concentration in surface waters remains well on the alkaline side while in most of the depressions the whole hypolimnion may become acid (to pH 6.7). The epilimnion shows small change, while the thermocline exhibits conspicuous fall in pH value. Except when made uniform by circulation, the usual fall tends to occur even in the absence of thermal stratification.

7. Thermal stratification normally leads to a chemical stratification in which the correlations are so close for all factors determined, except methyl orange alkalinity, that it is ordinarily possible to predict within very narrow limits the chemical distribution from a thermal stratification record. In the absence of thermal stratification the chemical features show either a more or less uniform distribution or a gradual change in the form of increase or decrease.

8. The summer unproductive volume of Douglas Lake, due to chemical changes in the lower waters, is small, usually less

than 10 per cent. Under conditions of no thermal stratification it may be wholly absent.

9. Results incorporated herein demonstrate clearly (1) the possible inadequacy of a single season's results as a dependable index of the expected sequence of events in a lake environment; and (2) the necessity of having reasonably complete hydrographic data in advance of physical-chemical determinations.

University of Michigan

TABLE VII

SUMMARY OF THERMAL STRATIFICATION IN THE DIFFERENT DEPRESSIONS

Approximately two hundred series of vertical temperature records have been made. Since all cannot be published, the following table presents a summary of records selected from the results of each season's work. The data for certain seasons which present no deviation from the usual type have been reduced to a minimum; those which exhibit special seasonal changes have been given more completely, although they also have been abbreviated.

The variation in the number of seasons over which the different depressions were studied reflects the history of the hydrographic information. Only two depressions were known at first; study of the others was begun in the order of their discovery.

All temperatures are expressed in degrees Centigrade. Thickness of the epilimnion and the hypolimnion, and limits of the thermocline, are stated in feet. The sign + indicates an increase, rather than the usual fall in temperature.

CAMP DAVIS DEPRESSION

Maximum Depth 79 feet

Date	Temperature		Epilimnion		Thermocline		Hypolimnion	
	Surface	Bottom	Thick-ness	Fall in Temp.	Limits	Fall in Temp.	Thick-ness	Fall in Temp.
1911								
July 10	24.7	8.3	23	1.4	23–46	12.8	33	2.2
1912								
July 19	20.5	10.0	39.3	3.0	39.3–52.5	7.0	26.5	0.5
1913								
July 7	21.4	9.2	37.7	2.4	37.7–44.9	6.0	34.1	3.8
Aug. 9	20.0	10.3	39	1.0	39–59	8.5	20	0.2
1914								
July 1	18.3	6.1	42.6	1.9	42.6–49	8.1	30	2.2
Aug. 19	22.5	7.3	36	2.2	36–52.5	11.1	26.5	1.9
1917								
July 4	19.9	8.6	40	5.7	40–50	4.0	29	1.6
Aug. 6	21.6	8.6	30	+0.1	30–50	11.2	29	1.9
1918								
July 10	19.0	14.9			No stratification			
July 24	23.1	14.7			No stratification			
1919								
July 10	20.5	8.6	27.5	1.0	27.5–40	7.7	39	3.2
1920								
July 9	20.2	7.9	40	2.5	40–55	9.1	24	0.7
Aug. 19	21.1	8.5	45	3.1	45–55	7.9	24	2.6
1921								
June 29	23.2	9.6	10	+1.6	10–50	11.4	29	3.8
July 11	27.9	9.2	15	1.5	15–50	15.9	29	1.3
July 20	23.1	9.6	30	1.0	30–55	11.7	24	0.8
July 30	23 4	8.9	30	1.5	30–55	11.3	24	1.7
Aug. 12	20.2	9.9	45	2.4	45–55	7.0	24	0.9
Aug. 22	19.0	9.2	47.5	1.2	47.5–55	7.0	24	1.6
1922								
June 7	21.6	6.4	15	1.2	15–60	13.8	19	0.2
June 16	19.0	6.2	30	1.8	30–50	8.7	29	2.3
July 5	19.0	6.7	35	0.1	35–50	9.0	29	3.2
July 26	20.2	7.0	45	3.4	45–60	9.5	19	0.3
Aug. 5	21.8	7.4	40	3.3	40–60	10.3	19	0.8
Aug. 16	25.5	7.5	40	6.0	40–55	9.4	24	2.6

CAMP DAVIS DEPRESSION (*Continued*)

Date	Temperature		Epilimnion		Thermocline		Hypolimnion	
	Surface	Bottom	Thickness	Fall in Temp.	Limits	Fall in Temp.	Thickness	Fall in Temp.
1923								
July 6	22.2	8.5	35	3.5	35–50	7.6	29	2.6
July 27	21.1	8.4	30	0.5	30–45	10.2	34	2.0
Aug. 17	20.5	9.0	45	2.2	45–55	8.5	24	0.8
1924								
July 2	20.2	10.9	40	3.5	40–50	5.7	29	0.1
Aug. 13	20.1	11.3	45	0.6	45–55	7.8	24	0.3
1925								
July 3	18.7	10.2	40	1.6	40–50	4.2	29	2.7
Aug. 2	22.6	10.2	45	4.3	45–55	7.2	24	0.9
1926								
June 22	17.2	6.8	52	3.6	52–59	6.7	20	0.1
July 1	19.0	6.5	49	3.2	49–59	6.0	20	3.3
July 13	18.7	6.9	49	1.4	49–65	9.9	14	0.5
Aug. 9	22.7	7.6	49	5.9	49–62	7.1	17	2.1
Aug. 26	19.3	8.2	49	1.3	49–62	7.9	17	1.9

SEDGE POINT DEPRESSION

Maximum Depth 79 feet

1917								
July 3	18.4	11.8			No stratification			
July 24	23.6	10.9			No stratification			
July 31	25.5	11.2	20	0.7	20–30	6.4	49	7.2
Aug. 6	22.2	11	50	7.0	50–60	3.9	19	0.3
1921								
Aug. 24	20.2	10.1	55	3.1	55–65	6.4	14	0.6
1922								
June 18	20.2	9.4	35	3.1	35–40	3.2	39	4.5
July 20	22.4	9.9	50	5.5	50–60	5.6	19	1.4
Aug. 5	21.8	9.9	45	3.5	45–60	7.5	19	0.9
Aug. 12	22.1	9.3	45	3.9	45–60	7.4	19	1.5
1923								
Aug. 9	20.4	10.3	35	0.3	35–50	8.0	29	1.8
1925								
Aug. 2	21.2	16.1	50	2.5	50–55	2.1	24	0.5
1926								
July 15	19.9	16.3			No stratification			
Aug. 27	20.1	16.9			No stratification			

GRAPEVINE POINT DEPRESSION

Maximum Depth 81 feet

1914								
July 22	23.3	15.8	26	2.5	26–39	4.1	42	0.9
1921								
July 7	29.4	11.1	20	5.6	20–40	9.0	41	3.7
July 21	26.4	11.1	25	3.2	25–45	9.7	36	2.4
Aug. 13	20	11.2	50	1.1	50–55	5.6	26	2.1
Aug. 22	19	10.6	60	1.5	60–65	6.2	16	0.7
1922								
June 18	20.2	9.4	45	4.5	45–50	5.0	31	1.3
July 4	16.3	9.8	45	+1.7	45–55	7.8	26	0.4
July 26	20.6	9.6	50	3.1	50–65	7.3	16	0.6
Aug. 16	24.6	9.9	45	6.3	45–65	7.5	16	0.9
1923								
Aug. 18	20.8	9.4	40	2.3	40–60	7.5	21	1.6
1925								
Aug. 2	20.3	16.8			No stratification			
1926								
July 14	19.5	18.3			No stratification			
Aug. 23	19.8	18.1			No stratification			

STONY POINT DEPRESSION

Maximum Depth 59 feet

Date	Temperature		Epilimnion		Thermocline		Hypolimnion	
	Surface	Bottom	Thick-ness	Fall in Temp.	Limits	Fall in Temp.	Thick-ness	Fall in Temp.
1922								
June 22	19.7	12.1			No stratification			
July 8	19.6	11.9			No stratification			
July 13	21.3	14.2	45	4.3	45–50	3.0	9	+0.2
July 20	20.6	14.3			No stratification			
July 29	22.4	16.4			No stratification			
Aug. 5	20.5	16.7	20	+2.0	20–25	4.7	34	1.1
Aug. 12	21.6	16.7	45	2.8	45–50	2.8	9	+0.7
1925								
Aug. 2	21.2	17.2			No stratification			
1926								
July 17	20	18			No stratification			
Aug. 27	20.2	18			No stratification			

ROBERTS POINT DEPRESSION

Maximum Depth 72 feet

1922								
July 31	21.6	9.6	30	0.8	30–55	9.6	17	1.6
Aug. 12	20.5	9.8	35	1.0	35–55	8.5	17	1.2
1925								
July 29	19.3	11.2	45	1.1	45–50	4.1	22	2.9
1926								
July 23	21.9	14.4	36	2.1	36–39	1.2	42	4.2
Aug. 3	24.4	15.3			No stratification			
Aug. 11	21.2	14.2			No stratification			
Aug. 16	21.5	14.0			No stratification			

FAIRY ISLAND DEPRESSION

Maximum Depth 89 feet

1914								
July 22	23.3	9.5	59	9.0	59–68	4.9	21	+0.1
1917								
July 3	17.5	11.4			No stratification			
July 12	18.3	11.1			No stratification			
July 18	19.8	10.8	40	4.4	40–50	3.2	39	1.4
July 24	24.7	10.9			No stratification			
July 31	25.1	11.1	20	2.9	20–50	9.6	39	1.5
Aug. 6	22	11.1	30	2.6	30–60	7.5	29	0.8
1918								
July 26	24.8	15.3			No stratification			
Aug. 16	22.2	15.6			No stratification			
1919								
July 30	21.8	10.3	32.5	1.4	32.5–40	8.3	49	1.8
1920								
Aug. 11	21.1	9.3	45	3.3	45–55	6.9	34	1.6
1921								
July 5	29.4	10.7	10	1.6	10–45	14.9	44	2.2
July 21	26.4	10.7	25	4.4	25–55	10.9	34	0.4
July 29	23.4	10.8	25	0.1	25–40	8.1	49	4.4
Aug. 9	20.8	10.3	40	1.5	40–50	6.5	39	2.5
Aug. 22	16.9	10.1	50	+0.3	50–60	5.6	29	1.5
1922								
June 18	17.4	7.9	35	+0.2	35–45	7.6	44	2.1
July 4	16.3	7.9	35	+1.4	35–45	6.7	44	3.1
July 26	23.2	8.7	40	5.2	40–50	7.0	39	2.3
Aug. 5	21.8	8.6	50	5.2	50–55	6.4	34	1.6
Aug. 16	24.3	8.5	35	4.3	35–55	9.9	34	1.6

FAIRY ISLAND DEPRESSION (*Continued*)

Date	Temperature		Epilimnion		Thermocline		Hypolimnion	
	Surface	Bottom	Thickness	Fall in Temp.	Limits	Fall in Temp.	Thickness	Fall in Temp.
1923								
Aug. 9	21.6	8.9	37.5	3.5	37.5–50	8.4	39	0.8
1924								
July 22	21.9	10.9	45	4.6	45–50	5.4	39	1.0
Aug. 18	19.1	11.8	55	3.8	55–60	2.6	29	0.9
1925								
July 29	18.8	11.4	50	2.6	50–65	4.6	24	0.2
1926								
July 16	19.6	9.4	59	2.2	59–78	7.7	11	0.3
July 28	22.8	12.0	62	6.0	62–72	3.8	17	1.0
Aug. 6	21.8	11.3	No stratification					

MAPLE POINT DEPRESSION

Maximum Depth 55 feet

1922								
Aug. 12	20.6	16.7			No stratification			
1923								
Aug. 18	20.7	16.4			No stratification			
1925								
July 29	20.8	17.2			No stratification			

TABLE VIII

Summary of Chemical Determinations

The following table presents a summary of chemical determinations selected from about one hundred and fifty series of analyses of vertical samples. The dates of the selected records are usually the same as those of the corresponding year in Table 7. For seasons manifesting no important deviation from the usual type, the data have been reduced to one or two records. Those presenting special seasonal features are given more fully, although all are reduced to a considerable extent.

Abbreviations: *t. s.*, thermal stratification; *unf.*, approximately uniform from surface to bottom; *c. s.*, chemical stratification; *c. gr.*, gradual quantitative reduction of dissolved oxygen, phenolphthalein alkalinity, and pH from surface towards bottom.

Dissolved oxygen is expressed in cubic centimeters per liter; free carbon dioxide in parts per million; and methyl orange alkalinity in parts per million of calcium carbonate. In the column for methyl orange alkalinity the first number is for surface water and the second is for bottom water.

CAMP DAVIS DEPRESSION

Date	Temperature Conditions	Chemical Conditions	Dissolved Oxygen		Free CO_2		Methyl-orange Alkalinity	pH	
			Surface-Bottom	Thermocline	Surface-Bottom	Thermocline		Surface-Bottom	Thermocline
1918									
July 24	no t. s.	unf.	6.06–7.64		0.0–24				
1920									
Aug. 19	t. s.	c. s.	5.81–0.0	2.35–0.0				8.0–7.0	7.3–7.0
1921									
July 11	t. s.	c. s.	3.06–0.0	3.39–0.24	0.0–24	0.0–10.5	122–119	8.4–7.1	8.2–7.2
July 20	t. s.	c. s.	3.53–0.0	2.96–0.0	0.0–16	0.0–16	119–118	8.6–7.2	8.2–7.2
July 30	t. s.	c. s.	4.59–0.0	2.01–0.0	0.0–28	6.0–27	119–124	8.6–7.1	7.7–7.2
Aug. 12	t. s.	c. s.	7.18–0.0	5.0–0.00	0.0–21	0.0–13	122–132	8.6–6.8	8.0–6.9
Aug. 22	t. s.	c. s.	6.61–0.0	3.7–0.0	0.0–23	0.0–13	120–131	8.5–6.8	8.0–6.9
1922									
June 16	t. s.	c. s.	5.93–0.41	5.79–5.02				8.2–7.0	7.6–7.3
July 5	t. s.	c. s.	5.58–0.0	5.16–2.30	0.0–10	0.0–9.0	126–130	8.2–7.0	8.1–7.2
July 26	t. s.	c. s.	4.68–0.0	2.44–0.14	0.0–15	0.0–5.7	125–132	8.2–6.8	7.3–6.8
Aug. 5	t. s.	c. s.	5.23–0.0	2.65–0.0	0.0–12	5.0–12	125–129	8.2–6.8	7.4–6.8
Aug. 16	t. s.	c. s.	4.4–0.0	2.16–0.0	0.0–17	5.0–10	126–131	8.2–6.7	7.3–6.8
1923									
July 6	t. s.	c. gr.	4.26–0.28	3.6–2.9				8.4–7.2	8.2–7.4
July 27	t. s.	c. s.	4.54–0.0	3.9–1.93				8.2–7.1	8.0–7.2
Aug. 17	t. s.	c. s.	5.44–0.0	5.0–0.35	0.0–6.0	0.0–4.5		8.4–7.2	8.1–7.2
1924									
July 2	t. s.	c. s.	4.15–0.14	3.14–3.14	0.0–5.5	0.0–2.0	128–121	8.3–7.0	8.2–7.5
Aug. 13	t. s.	c. s.	5.5–0.0	5.4–0.0	0.0–12	0.0–5	115–124	8.2–7.0	8.2–7.1
1925									
July 3	t. s.	c. s.	6.39–0.0	5.61–1.75	0.0–6.4	1.4–3.4		8.2–7.0	7.6–7.2
Aug. 2	t. s.	c. s.	5.46–0.0	4.76–1.33	0.0–14.3	1.1–10.4		8.4–7.0	8.2–7.3
1926									
July 1	t. s.	c. s.	6.05–0.0	5.0–0.61				8.4–7.2	8.3–7.3
July 13	t. s.	c. s.	6.16–0.0	4.67–0.0	0.0–19	4.0–15	126–130		
Aug. 9	t. s.	c. s.	6.28–0.0	5.0–0.0			125–131	8.5–7.1	8.2–7.2
Aug. 26	t. s.	c. s.	6.77–0.0	3.9–0.0	0.0–19	1.0–13	125–138	8.5–7.0	7.8–7.1

SEDGE POINT DEPRESSION

Date	Temperature Conditions	Chemical Conditions	Dissolved Oxygen		Free CO_2		Methyl-orange Alkalinity	pH	
			Surface-Bottom	Thermocline	Surface-Bottom	Thermocline		Surface-Bottom	Thermocline
1922									
June 18	t. s.	c. gr.	3.9–1.04	4.05–2.58				7.8–6.8	7.4–7.2
July 20	t. s.	c. s.	6.21–0.0	4.19–0.07	0.0–16	7–15	125–132	8.2–6.8	7.4–6.9
Aug. 5	t. s.	c. s.	5.09–0.0	0.97–0.0	0.0–10	6–10	125–130	8.2–6.8	7.2–6.9
Aug. 12	t. s.	c. s.	4.74–0.0	2.44–0.0	0.0–14	8–12	136–135	8.2–6.8	7.2–6.8
1923									
Aug. 18	t. s.	c. s.	5.72–0.0	5.72–0.01				8.1–7.1	7.9–7.1
1925									
Aug. 2	t. s.	c. s.	5.18–0.14	3.43–1.26	0.0–7.7	1.1–6.6		8.4–7.1	8.1–7.4
1926									
July 15	no t. s.	c. gr.	4.04–0.0					8.5–7.2	
Aug. 27	no t. s.	c. gr.	6.56–3.38		0.0–3.0		122–125	8.6–7.6	

GRAPEVINE POINT DEPRESSION

1921									
July 7	t. s.	c. s.	2.51–0.0	3.14–0.55	0.0–6.0	0.0–5.0	124–120	8.3–7.2	8.4–7.2
July 21	t. s.	c. s.	4.2–0.0	4.0–0.0	0.0–12	0.0–12.0	118–118	8.6–7.4	8.6–7.4
July 29	t. s.	c. s.	3.78–0.0	3.9–0.0	0.0–21	0.3–20.0	120–122	8.6–7.2	7.8–7.2
Aug. 13	t. s.	c. s.	6.94–0.0	2.94–0.29			121–124	8.5–7.0	7.5–7.0
Aug. 22	t. s.	c. s.	6.4–0.0	4.43–0.0	0.0–21	0.4–12	120–126	8.4–7.0	7.8–7.0
1922									
June 18	t. s.	c. s.	3.91–1.12	3.70–4.19				7.8–7.0	7.6–7.2
July 4	t. s.	c. s.	5.44–0.28	5.23–1.9	0.0–13	18–14	124–125	8.2–7.2	7.8–7.2
July 26	t. s.	c. s.	5.23–0.0	2.58–0.0	0.0–15	7–13	125–126	8.2–6.8	7.3–6.8
Aug. 5	t. s.	c. s.	5.44–0.0	0.98–0.0	0.0–11.3	8.5–11	125–127	8.2–6.8	7.0–6.8
Aug. 16	t. s.	c. s.	4.95–0.0	2.23–0.0	0.0–15	7–13	124–131	8.2–6.8	7.3–6.8
1925									
Aug. 2	no t. s.	c. gr.	5.81–0.21		0.0–11			8.4–7.2	
1926									
July 14	no t. s.	unf.	6.10–5.06					8.4–8.2	
Aug. 23	no t. s.	unf.	6.0–5.58		0.0–0.0		125–129	8.5–8.2	

STONY POINT DEPRESSION

1922									
June 22	no t. s.	c. gr.	3.21–1.18					7.8–7.0	
July 8	no t. s.	c. s.	5.58–0.0					8.1–7.1	
July 13	t. s.	c. gr.	5.3–2.86	4.95–4.88	0.0–8.0	0.0–2.0	124–131	8.0–7.2	8.0–7.8
July 20	no t. s.	c. gr.	5.09–1.32		0.0–10		125–128	8.2–7.2	
July 29	no t. s.	c. gr.	5.3–0.0		0.0–11		125–132	8.2–7.0	
Aug. 5	t. s.	c. s.	6.0–0.0	4.40–4.47	0.0–10.5	0.0–0.0	124–131	8.2–7.1	8.2–8.1
Aug. 12	t. s.	c. s.	5.65–0.0	1.67–0.0	0.0–10	10–8	124–133	8.2–7.0	7.4–7.1
1925									
Aug. 2	no t. s.	c. gr.	5.32–2.94		0.0–6.6			8.4–7.3	
1926									
July 17	no t. s.	unf.	6.09–4.95					8.4–7.8	
Aug. 27	no t. s.	c. gr.	6.49–0.06		0.0–11		122–129	8.4–7.4	

ROBERTS POINT DEPRESSION

1922									
July 31	t. s.	c. s.	5.65–0.0	4.33–0.0	0.0–10	0.0–9.0	124–123	8.2–6.8	8.0–6.9
Aug. 12	t. s.	c. s.	4.19–0.0	4.54–0.0	0.0–11	0.0–10	124–129	8.2–6.8	8.0–6.9
1925									
July 29	t. s.	c. s.	4.76–0.14	3.92–2.59				8.4–7.1	
1926									
July 23	t. s.	c. gr.	6.27–0.03		0.0–13.4		125–134	8.4–7.2	8.4–8.3
Aug. 3	no t. s.	c. s.	6.28–0.0		0.0–16		125–134	8.5–7.2	
Aug. 11	no t. s.	c. s.	6.49–0.0		0.0–16		124–132	8.6–7.2	
Aug. 16	no t. s.	c. s.	6.35–0.0		0.0–16		124–132	8.5–7.2	

FAIRY ISLAND DEPRESSION

Date	Temperature Conditions	Chemical Conditions	Dissolved Oxygen		Free CO_2		Methyl-orange Alkalinity	pH	
			Surface-Bottom	Thermocline	Surface-Bottom	Thermocline		Surface-Bottom	Thermocline
1918									
July 26	no t. s.	unf.	6.0–7.46		0.0–3.5				
Aug. 16	no t. s.	unf.	6.0–6.00		0.0–1.0				
1920									
Aug. 11	t. s.	c. s.	6.87–0.15	5.2–2.64				8.0–7.0	7.8–7.2
1921									
July 5	t. s.	c. s.	2.58–0.06	2.23–0.37	0.0–17	0.0–4.0	126–119	8.4–7.0	8.3–7.3
July 21	t. s.	c. s.	4.4–0.0	4.5–0.0	0.0–16	0.5–12	119–118	8.6–7.2	8.6–7.4
July 29	t. s.	c. s.	4.0–0.0	4.3–0.76	0.0–23	0.0–17	121–119	8.6–7.2	8.4–7.3
Aug. 9	t. s.	c. s.	6.53–0.0	4.86–0.47	0.0–15	0.0–9	121–121	8.5–7.0	8.0–7.1
Aug. 22	t. s.	c. s.	5.35–0.0	3.63–0.0	0.0–21	5.0–14	122–126	8.4–6.9	7.8–7.0
1922									
June 18	t. s.	c. gr.	4.81–0.63	3.84–2.65				7.8–7.1	7.5–7.2
July 4	t. s.	c. s.	5.0–0.0	5.0–3.87	0.0–10	0.3–0.8	126–126	8.2–7.2	8.2–7.5
July 26	t. s.	c. s.	4.74–0.0	3.42–1.25	0.0–19	5–9	125–127	8.2–6.8	7.4–7.0
Aug. 5	t. s.	c. s.	4.74–0.0	0.63–0.42	0.0–12	8–9	125–128	8.2–6.8	6.8–6.8
Aug. 16	t. s.	c. s.	4.26–0.0	4.26–0.0	0.0–16	0.0–11	125–127	8.2–6.8	7.6–6.8
1924									
July 22	t. s.	c. s.	5.1–0.07	4.6–3.35	0.0–8.0	0.0–2.5	114–118	8.0–7.0	7.8–7.4
Aug. 18	t. s.	c. s.	4.4–0.0	4.5–3.35	0.0–7.5	0.0–4.5	109–117	8.2–7.0	8.0–7.4
1925									
July 29	t. s.	c. s.	5.32–0.02	3.57–0.07	0.0–49.5			8.4–7.0	8.0–7.2
1926									
July 16	t. s.	c. s.	5.30–0.0	2.58–0.0				8.4–7.2	7.6–7.2
July 28	t. s.	c. s.	6.56–0.0	0.55–0.20	0.0–16	8–10	126–135	8.4–7.2	7.4–7.4
Aug. 6	no t. s.	c. s.	6.7–0.0		0.0–18		215–122	8.7–7.3	

MAPLE POINT DEPRESSION

1921									
Aug. 12	no t. s.	c. s.	5.65–0.0		0.0–10		124–132	8.2–7.2	
1925									
July 29	no t. s.	unf.	5.18–4.55					8.4–8.2	

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